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RESIDENTIAL LOCATION
and
MODE of TRANSPORTATION to WORK:
A MODEL of CHOICE

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CHICAGO AREA TRANSPORTATION STUDY

Sponsored By

STATE OF ILLINOIS, COOK COUNTY, AND CITY OF CHICAGO

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RESIDENTIAL LOCATION AND MODE OF TRANSPORTATION TO WORK

A MODEL OF CHOICE

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PART I. INTRODUCTION

A. PROBLEM.

With the growth in importance of urban areas, there has been increasing concern on the part of social scientists with the internal growth and structure of cities. It is obvious from the vast quantities of literature which have come forth that the complexity of the topic is enormous and that much is yet to be accomplished. This study is concerned with one limited topic within this whole, the selection of a residential location by households.

Basic to the study is the assumption that the distribution of residences is not random, but rather that it has some regularity which can be explained systematically. It is hypothesized that a major factor in the choice of a residential site is its location with relation to the place of work. This hypothesis is based on the work trip expenditure as a large and significant part of the household budget[1] and on the importance of time to the commuter. For most households, the work trip so dominates the travel budget that successful analysis may be based on work trip patterns as the explanation of the residential location pattern. The hypothesis may be made more explicit. Households substitute journey-to-work expenditures for residential site expenditures. However, since choice of residential site is related to such additional factors as the schedule of location-rents, individual preferences for residential space, and the level of household income, these must also be taken into account in any investigation. The mode of travel chosen by the individual for the journey to work also influences the residential location decision. If the hypothesized substitution between travel and site expenditures takes place, then differences in travel cost between modes should influence the point of substitution. Therefore, travel mode is a further important ingredient of the study.

B. PURPOSE.

It is hoped that this study will contribute to the understanding of the relationships between residential location and transportation in urban areas. In a policy sense, such a contribution will be invaluable because transportation planners need models which have been adequately tested. Thus, not only is this study an academic exercise in model construction and testing, but also a step in the development of a workable planning tool.

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[1]Kain, John F., "The Journey to Work as a Determinant of Residential Location" (unpublished Ph.D. dissertation, Department of Economics, University of California, 1961), p. 1.

Although economists have been concerned with land rent and location since at least the eighteenth century, interest in urban land values is a relatively recent development. In the period before 1900, theorists who discussed the relation of land values to land uses were concerned primarily with agricultural land.[1] A notable exception was Alfred Marshall,[2] whose main interest in urban areas was land values related to profit-making land uses. His major contribution to later work on residential land values was a recognition of the significance of site size.

A. URBAN LAND ECONOMISTS.

Many of the theoretical insights into the relationships between transportation costs, location-rents, and the distribution of land uses in an urban area have come from the work of the "Classical Urban Land and Real Estate School." Under this heading are included such persons as Richard M. Hurd, Robert M. Haig, Homer Hoyt, and Richard U. Ratcliff.[3]

Hurd, in discussing the relationships between location, accessibility, and economic rents, pointed out a basic relationship:

> "Since land value depends on economic rent, and rent on convenience, and convenience on nearness, we may eliminate the intermediate steps and say that value depends on nearness. The next question is nearness to what? -- which brings us to the land requirements of different utilities, their distribution over the city's area and the consequent creation and distribution of values."[4]

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[1] Ricardo, David, On the Principles of Political Economy and Taxation (Homewood, Illinois: R. D. Irwin, 1963). Smith, Adam, The Wealth of Nations (New York: The Modern Library, c. 1937). Mill, John Stuart, Principles of Political Economy (New York: Appleton and Co., 1884).

[2] Marshall, Alfred, Principles of Economics (London and New York: Macmillan and Co., 1890).

[3] Hurd, Richard M., Principles of City Land Values (New York: The Record and Guide, 1903). Haig, Robert M., "Toward an Understanding of the Metropolis," Quarterly Journal of Economics, Vol. XL, No. 3 (May, 1926); and Regional Survey of New York and Its Environs (New York: New York City Planning Commission, 1927). Hoyt, Homer, The Structure and Growth of Residential Neighborhoods in American Cities (Washington, D.C.: U.S. Government Printing Office, 1939). Ratcliff, Richard U., Urban Land Economics (New York: McGraw-Hill Book Company, Inc., 1949).

[4] Hurd, op. cit., p. 12.

Haig continued this line of thought, postulating that, "The theoretically perfect site for the activity is that which furnishes the desired degree of accessibility at the lowest cost of friction."[5] The household will maximize its utility, according to Haig, by selecting the site which allows it to obtain the best combination of goods and services available at the lowest possible friction costs. Friction costs are defined as the sum of transportation costs and site rentals.

Hurd did not allow, however, the applicability of his model to residential location. He stated that the "main consideration in the individual selection of a residence location is the desire to live among one's friends or among those whom one desires to have for friends."[6] This statement may be, as Kain claims, the seed of the "Hoyt Sector Theory,"[7] which is "held by real estate economists to be a theory of city growth and structure."[8] Kain considers it to be a static theory of residential location, or less charitably, "it is a description of the pattern of average rents per block in a fairly large number of American cities in 1939, loosely associated with the pattern of nonresidential uses and crudely tied to aspects of the cities' transportation network."[9]

B. HUMAN ECOLOGISTS.

Human ecologists hold a view of urban land values which is similar to that of the urban land economists. The two disciplines have, however, remained distinct, with the land economists associated mainly with economics and the ecologists with sociology. Because of their sociological orientation, ecologists are greatly interested in residential location.

The statement by Park and Burgess, "Land Values are the chief determining influence in the segregation of local areas and in the determination of the uses to which an area is put,"[10] demonstrates a similarity of thought with the urban land economists. Haig, however, pointed out a significant difference in viewpoint: "But is it not the uses which determine land values rather than vice versa?"[11]

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[5] Haig, "Toward an Understanding . . . ," loc. cit., p. 418.

[6] Hurd, op. cit., p. 78.

[7] Hoyt, op. cit.

[8] Kain, op. cit., p. 8.

[9] Kain, op. cit.

[10] Park, Robert E., and Burgess, Ernest W. (eds.), The City (Chicago: University of Chicago Press, 1925), p. 203.

[11] Haig, op. cit., p. 405, fn. 4.

More in agreement with Haig's reply is the statement by Hawley that "familial units are distributed with references . . . to land values, the locations of types of units, and the time and cost of transportation to centers of activity . . . The influence of the three factors are combined in a single measure, namely, rental value for residential use."[12]

Walter Firey[13] has attacked the determination of location by land values. He considers "sentiment" to be of major importance. Partly in reaction to Firey's criticism, the theory has been generalized to include noneconomic factors. Quinn states it in this way: "Ecological units tend to distribute themselves throughout an area so that the total costs of gaining maximum satisfaction in adjusting population to environment are reduced to the minimum . . . As used in this hypothesis, the concept of cost . . . embraces whatever value is given up or is enjoyed in lesser degree in obtaining any given pattern of adjustment."[14]

C. URBAN GEOGRAPHERS.

The literature of urban geography indicates an emphasis on general questions of intra-metropolitan spatial structure and forces. It has been influenced by all of the orientations discussed in this chapter.

Charles C. Colby's discussion[15] of centripetal and centrifugal forces acting in intra-urban location refers to movements and consequent patterns formed. He includes the residential function in his analysis as well as industrial and commercial uses.

Generalization of internal patterns of cities are the basis from which Harris and Ullman[16] go on to look at the forces which underlie land use. They

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[12]Hawley, Amos H., Human Ecology (New York: Ronald Press, 1950), p. 280.

[13]Firey, Walter, Land Uses in Central Boston (Cambridge, Mass.: Harvard University Press, 1947).

[14]Quinn, James A., Human Ecology (New York: Prentice-Hall, 1950), p. 282.

[15]Colby, Charles C., "Centrifugal and Centripetal Forces in Urban Geography," in Harold M. Mayer and Clyde F. Kohn (eds.), Readings in Urban Geography (Chicago: University of Chicago Press, 1959), pp. 287-298.

[16]Harris, Chauncy D., and Ullman, Edward L., "The Nature of Cities," ibid., pp. 277-286.

incorporate the Burgess and Park concentric zonal hypothesis and Hoyt's hypothesis of axial development, as well as postulating a third arrangement of multiple nuclei. Later work by T. R. Anderson[17] has substantiated these three patterns by use of factor analysis.

D. CONTEMPORARY LAND USE THEORY.

Works falling under the heading "contemporary land use theory" represent efforts to develop and test models of spatial organization in urban areas. They are conceptually differentiated from the work done in applied urban research by their greater emphasis on theory. The distinction, however, is not a precise one.

Independently conceived theoretical works by Wingo[18] and Alonso[19] use similar methods and come to similar conclusions on the interrelated problems of location, land use, and transportation in urban areas, even though some of their assumptions differ slightly. Wingo keeps separate the preferences for accessibility and for living space, whereas in Alonso's approach they are interrelated, but kept distinct from budgetary considerations until joined in terms of marginal rates of substitution and marginal costs. This difference appears to be the basis for the major points of divergence between the two works.

Hoover and Vernon[20] view residential location in terms of an existing housing supply and its gradual evolution. They see evidence of a "balancing" operation in which the incentive to live near jobs and other urban attractions (a concentrating force) is opposed by resistances to concentration and high density based in part on a desire for spacious living.

E. INDUSTRIAL LOCATION.

Industrial location theory is another source in the literature from which to draw material relevant to the problem of residential location. The theoretical

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[17]Anderson, Theodore R., and Egeland, Janice A., "Spatial Aspects of Social Area Analysis," American Sociological Review, XXVI (1961), 392-398.

[18]Wingo, Lowdon, Jr., Transportation and Urban Land (Baltimore: The Johns Hopkins Press, 1961).

[19]Alonso, William, Location and Land Use (Cambridge, Mass.: Harvard University Press, 1964).

[20]Hoover, Edgar M., and Vernon, Raymond, Anatomy of a Metropolis (Cambridge: Mass.: Harvard University Press, 1959).

formulations of the school[21] at first seem appealing. Under closer scrutiny, however, there appear to be several basic differences between the two problems. The profit maximization objective which is generally postulated for the firm becomes the maximization of the satisfaction obtainable from total household income when the question of residential location is considered.[22] Cost of transporting labor is generally not considered or is treated only in passing by industrial location theorists. This creates an insurmountable obstacle to the incorporation of this approach into the present study, since time and money costs of transportation to work are a major portion of the household's total transportation outlay. In addition, industrial location models often abstract from the quantity of space used by the firm or from the price it pays for that quantity. The factors discussed above (costs of transportation, quantity of space utilized, price of space) are the bases of the explanatory scheme for residential location which is utilized in this study.

The concept of the consumer's space preference (a measure of the individual's desired level of social contact) proposed by Isard indicates that different individuals placed in the same spatial situation and with the same amounts of information may act differently. He hypothesizes that these differences in behavior are due to differences in the space preferences of these individuals. With major differences between the factors which, theoretically, influence the two location problems, it can be seen that to this analysis from the industrial location school substantive contributions will be limited in number.

F. APPLIED URBAN RESEARCH.

Metropolitan transportation studies have made major contributions to the understanding of urban spatial organization, in particular, through the empirical testing of theoretical formulations. Because it is necessary for them to predict future land uses and population densities, they have had to devise new constructs or to improve on previous analytical formulations in order to meet their needs.[23]

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[21] Weber, Alfred, Theory of the Location of Industries, translated by C. J. Friedrich (Chicago: University of Chicago Press, 1928); Losch, August, The Economics of Location, translated by W. H. Woglom with the assistance of W. F. Stolper (New Haven: Yale University Press, 1954); Hoover, Edgar M., Location Theory and the Shoe and Leather Industries (Cambridge, Mass.: Technology Press of the Massachusetts Institute of Technology, 1937); Isard, Walter, Location and Space-Economy (Cambridge, Mass.: Massachusetts Institute of Technology Press, 1956).

[22] An alternative assumption is that the individual and the household tend to satisfice, rather than optimize. In satisficing, according to Julian Wolpert, "The individual is adaptively or intendedly rational rather than omnisciently ration. Alternatives are considered which are conspicuous (i. e., about which he has received information)." ("The Decision Process in Spatial Context," Annals of the Association of American Geographers, LIV [1964], 558).

[23] Lathrop, George T., and Hamburg, John R., "An Opportunity-Accessibility Model for Allocating Regional Growth," Journal of the American Institute of Planners, XXXI (May, 1965), 95-103. Schlager, Kenneth J. "A Land Use Plan Design Model," ibid., p. 103-111. Hill, Donald M., "A Growth Allocation Model for the Boston Region," ibid., p. 111-120. Chapin, F. Stuart, Jr., "A Model for Simulating Residential Development," ibid., p. 120-125. Lakshmanan, T. R., and Hansen, Walter G., "A Retail Market Potential Model," ibid., p. 134-143. Lowry, Ira S., "A Short Course in Model Design," ibid., p. 158-166.

Residential location and land use are of interest to planners because they are required as inputs into their trip generation models. Traffic flows are described and predicted, at least in part, as a function of kinds of urban land use. In order to predict the flows, residential location and population densities must first be predicted. Generally, such predictions have been simple in concept, but increasingly they have become more sophisticated and have provided insights into the problems of spatial organization in urban areas.

G. SYNTHESIS.

A number of ideas about residential location selection by households can be drawn from these several bases:

1. There is a direct relationship between land values and accessibility.

2. Family units are distributed according to the location of types of units and the time and cost of transportation.

3. The location decision of households is influenced by "sentiment."

4. Desired level of social contact (space preference) varies among individuals.

5. Residential location is influenced by the mode of transportation chosen for the journey to work.

These are incorporated in the model that follows.

A. INTRODUCTION.

A model may be defined as an idealized representation of an abstract logical construct, "a way to express significant causal or structural relationships stripped of the irrelevancies and complexities of the real world so that they may be more readily understood."[1] This study employs a modification of a consumer choice model used by John F. Kain in a series of works[2] on the Detroit Metropolitan Area. The Kain model employs least-squares multiple regression techniques to explain variations in residential and trip-making behavior.

A question may be raised about whether the decision-making unit should be considered to be the household or the individual. In this study, some decisions are made by the household as a unit, while in other cases the individual acts independently. This situation does not cause a problem in the study, since the structure of Kain's model allows the characteristics of both units to be employed.

Four types of locational and trip-making behavior are measured by the seven equations and two identities of the model. Because causality is assumed, the order of these equations is critical. Information from the first equations is used in the later ones. In the sequence it is assumed that the household first chooses the residential density at which it wishes to live. A decision is then made about purchasing an automobile. This decision is influenced by the previous decision on residential space consumption. The next decision, whether to drive or take public transit to work, is affected by both previous choices. The location of residence, as measured by the length of the journey to work, is dependent upon choices made about residential space consumption and mode of transportation.

Following this reasoning, the model may then be written as follows:

1. Exogenous Variables.

Y_j = the median family income of j's workers;

P_j = the mean front-foot value of residential land in Zone j;

S_j = the percentage of Zone j's workers who are male;

N_j = the labor-force participation rate of Zone j's workers;

B_j^1 = the level of bus transit service in the j-th zone;

B_j^2 = the level of rapid transit service in the j-th zone;

F_j = the family size of Zone j's workers;

D_j = the population density of the j-th zone.

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[1]Wingo, op. cit., p. 9.

[2]See titles of Kain's works in Bibliography.

2. Endogenous Variables.

R^s_j = the percentage of Zone j's workers residing in single family housing units;

R^2_j = the percentage of Zone j's workers residing in two-family units;

R^m_j = the percentage of Zone j's workers residing in multiple units;

R^o_j = the percentage of Zone j's workers residing in other types of dwelling units -- rooming houses, hotels, trailers, etc.;

A_j = the mean automobile ownership of Zone j's workers;

M^a_j = the percentage of Zone j's workers who drive automobiles to work;

M^b_j = the percentage of Zone j's workers who ride public transit to work;

M^o_j = the percentage of Zone j's workers using other modes;

T_j = the mean elapsed time spent by Zone j's workers in reaching work.

3. Underlying Assumptions.

1. There are systematic differences in the labor forces of the various zones and within the zones which are reflected in and largely explained by the independent variables used in the model;

2. These systematic differences are reflected in the specific aggregation procedures used.[3]

4. Equations.

(1. a.) $R^s_j = \alpha_o + \alpha_1 F_j + \alpha_2 Y_j + \alpha_3 P_j + \alpha_4 S_j + \alpha_5 N_j + \alpha_6 D_j$

(1. b.) $R^2_j = \alpha_o' + \alpha_1'F_j + \alpha_2'Y_j + \alpha_3'P_j + \alpha_4'S_j + \alpha_5'N_j + \alpha_6'D_j$

(1. c.) $R^m_j = \alpha_o'' + \alpha_1''F_j + \alpha_2''Y_j + \alpha_3''P_j + \alpha_4''S_j + \alpha_5''N_j + \alpha_6''D_j$

(1. d.) $R^o_j + 1.0 - (R^s_j + R^2_j + R^m_j)$

[3] Kain, John F., A Contribution to the Urban Transportation Debate: An Econometric Model of Urban Residential and Travel Behavior, P-2667 (Santa Monica, Calif.: Rand Corporation, 1962), p. 9.

$$(2.)\quad A_j = \beta_o + \beta_1 R_j^s + \beta_2 Y_j + \beta_3 B_j^1 + \beta_4 S_j + \beta_5 F_j + \beta_6 B_j^2 + \beta_7 D_j$$

$$(3.a.)\quad M_j^a = \gamma_o + \gamma_1 A_j + \gamma_2 R_j^s + \gamma_3 B_j^1 + \gamma_4 Y_j + \gamma_5 S_j + \gamma_6 N_j + \gamma_7 B_j^2 + \gamma_8 D_j$$

$$(3.b.)\quad M_j^b = \gamma_o' + \gamma_1' A_j + \gamma_2' R_j^s + \gamma_3' B_j^1 + \gamma_4' Y_j + \gamma_5' S_j + \gamma_6' N_j + \gamma_7' B_j^2 + \gamma_8' D_j$$

$$(3.c.)\quad M_j^o = 1.0 - (M_j^a + M_j^b)$$

$$(4.)\quad T_j \quad \delta_o + \delta_1 R_j^s + \delta_2 S_j + \delta_3 Y_j + \delta_4 P_j + \delta_5 N_j + \delta_1 M_j^b + \delta_7 D_j$$

B. DISCUSSION OF INDEPENDENT VARIABLES.

The exogenous, or independent variables employed in the study are basically the same as those used by Kain in Detroit.[4] A few additions and modifications have been made because of special local conditions or improved data.

1. Price of Residential Space.

John Kain, in defining his measure for the price of residential space, gave the following provisional hypothesis:

> "That there is a market for residential space, and that there exists in each urban area a set of prices or rents for residential sites that varies from one location to another ; these prices are economic rents that landlords can obtain for more accessible sites because of households' collective efforts to economize journey-to-work travel costs; these rents (. . . location-rents) are a direct function of distance from major workplaces and the level of employment at these workplaces, and an inverse function of the supply of urban space available around these workplaces."[5]

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[4] Ibid.

[5] Ibid., p. 15.

Based on the hypothesized decline of land values at increasing distance from the center of the city, Kain uses a location-rent proxy defined as "11.5 minus the zone's distance in miles from the Central Business District, with a minimum value of 0.5."[6] Using this reasoning, it might also be expected that land values should rise toward the highest value intersections of such smaller commercial areas as are located in Skokie. Kain takes no account of secondary peaks in his measure.

Another inadequacy of Kain's measure is the use of a straight line price-distance measure. Berry, Simmons, and Tennant[7] have verified Muth's[8] assumption that the price-distance function from city center is negative exponential.

Yeates[9] points out in his article on land values in Chicago that in his model, which is similar to the one being tested in this study, the decline in importance of the variable distance from the Central Business District is largely responsible for the decline in power of the model through the period under study, 1910-1960. He explains this decline in land values and population densities at the city center in terms of changing location preferences. A number of factors have been influential in this change, such as: "the universal use of the automobile, the construction of highways and expressways, the shorter work week, increasing wages, and increased leisure."[10] With the weakened negative relation between distance from Central Business District and land values, it is expected that more rapid growth of land values at the city's periphery should be noticeable.

In an effort to alleviate the shortcomings discussed above, the front-foot land values for each housing unit interviewed was obtained from Olcott's Land Values Blue Book of Chicago.[11] An additional reason for using front-foot land values was that distance from the Chicago Central Business District

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[6] Ibid., p. 16.

[7] Berry, Brian J. L., Simmons, James W., and Tennant, Robert J., "Urban Population Densities: Structure and Change," Geographical Review, LIII (1963), 389-405.

[8] Muth, Richard F., "The Spatial Structure of the Housing Market," Papers and Proceedings of the Regional Science Association, VII (1961), 207-220.

[9] Yeates, Maurice H., "Some Factors Affecting the Spatial Distribution of Chicago Land Values, 1910-1960," Economic Geography, XLI (1965), 57-70.

[10] Ibid., p. 59.

[11] Olcott's Land Values Blue Book of Chicago, 1964, (Chicago: Scribner and Co., 1964).

would show little spatial differentiation within such a small area unit as Skokie. Since Skokie is part of a larger metropolitan area, it would be inappropriate to use distance from Skokie's city center.

2. Family Income.

Median household income for each zone, the income measure employed in this study, was drawn from responses to a question in the Skokie home interviews. It is expected that this measure will yield more reliable results than that employed by Kain in his Detroit study. Since an income question was not included in the Detroit questionnaire, it was necessary for Kain to use the median income of occupational group and sex in Detroit, as drawn from the U.S. Census of Population. Family income was approximated by summing these median incomes over all working members of each household.

3. Preference Variables.

The space preference variables represent an attempt to stratify the working population into groups which evidence a greater or lesser preference for residential space. Three related measures of preference have been used: sex ratio, labor force participation rate, and family size.

The sex ratio, or percentage of a zone's workers who are male, is intended to differentiate between male and female members of the labor force in order to separate their residential and travel patterns.

Labor force participation is measured by the percentage of employed persons in a zone belonging to families having a single wage earner. Families with more than one wage earner tend to be smaller, which should influence their propensity to consume residential space and their residential location decisions.

The family-size variable used in this study is defined as the percentage of a zone's workers belonging to families of more than two persons.

4. Transit Variables.

In order for the consumer to utilize public transit, it must be available to him. Accessibility to transit (the degree to which it is available to the commuter) has been measured in this study by two indexes, one for bus facilities and one for rapid transit service. These indexes measure both distance and seating capacity. Implicitly, they also include regularity and frequency of service, since these generally accompany increased seating capacity. Cost of transit fare has not been included in the index because of the small difference between the forms of public transit. Walking time and waiting time between transfers also have been excluded, because this information was unavailable.

An index for commuter train service was not incorporated into the model, because there were no individuals in the subsample who used commuter trains. In a study of a metropolitan region, however, it would be desirable to devise an index for commuter rail service similar to the two discussed above.

The bus accessibility variable in this study is a modification of the one used in Kain's study. His measure of bus accessibility was total coach-miles of bus service in a zone for a twenty-four hour weekday period. Since most of the bus routes in Skokie fall on streets which bound the analysis zones, this measure proved to be ambiguous. In addition, a coach-mile measure does not take into account where the route passes through the zone. Consequently, a related measure was devised for this study. The measure is an index based on number of coaches[12] passing through a zone during a twenty-four hour weekday and weighted by an approximate measure of the mean distance of the bus route from the zone's centroid.[13]

No rapid transit variable was employed in Kain's model because he tested it using Detroit data, and Detroit has no rapid transit system. As with bus accessibility, the rapid transit accessibility variable in this study is a measure of seating capacity weighted by a measure of distance from the zone's centroid.[14]

5. Population Density.

The population density measure (population[15] per standardized unit area) in this study was a gross figure for each analysis zone. Gross density is a measure in which population is weighted by total area in the zone, regardless of land use. Muth[16] found that a net population density measure, or population weighted by land in residential use, is to be preferred over gross density. However, there were no current and reliable data available on Skokie land use by the quarter-section analysis zones used in this study.

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[12]Number of coaches is an approximation of the desired measure, seating capacity. In this case, it is an acceptable surrogate, because seating capacity is approximately the same for all the coaches operated in Skokie.

[13]See Appendix II for method.

[14]See Appendix II for method.

[15]For this study, population figures by zone were taken from the factored results of the Skokie Home Interviews.

[16]Muth, *op. cit.*

C. DISCUSSION OF DEPENDENT VARIABLES.

The dependent or endogenous variables represent the decisions made by the individuals and households. It is the purpose of the model to approximate as nearly as possible, by means of regression analysis, the results of each of the four choices under study at the aggregate level of the quarter section.

1. Residential Space Consumption.

The measure of residential space consumption employed in this study is the same as that used by Kain in his study of Detroit, housing unit type.

> "A housing unit is usually a group of rooms or a single room occupied as separate living quarters by a family. However, a unit may also be occupied by a group of unrelated persons living together or by a person living alone. Vacant living quarters which are intended for occupancy as separate quarters are also housing units."[17]

Housing-unit type is defined in terms of the number of housing units in a structure.[18] For ease of handling, three types were considered: single, double, and multiple units.

A difficulty in the use of housing-unit type as a surrogate for residential space consumption is that it fails to take into account variations in lot size, which would seem to be particularly important in the case of single-family structures. Although lot size or, in the case of multiple-unit structures, some proportion of land use, would be a preferred measure, this information was not readily available in a usable form for the Village of Skokie.

Kain mentions the possibility of weighting the lot-size figure, especially for multiple-unit structures, by a measure of neighborhood density and density of the immediate community, although he does not go on to explain the criteria he would use to define such areas. In this study, gross population density by zone was an independent variable in the estimating equations for residential space consumption.

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[17] Chicago Area Transportation Study, Mass Transit Demonstration Project Home Interview Manual, 1964 (Chicago: CATS, 1964), p. 8.

[18] "A separate structure has:
 i. Open space on all four sides; or
 ii. Permanent vertical walls dividing it (from ground to roof) from all other structures."
ibid., p. 26.

As indicated previously, the ordering of the model's estimating equations is based on a hypothesized pattern of behavior by the decision-making unit, which, in the case of residential space consumption, is assumed to be the household. Level of household income defines an upper limit to what may be acquired, and indicates, in general terms, a propensity to consume. The limit is relative, however, to the price level of residential space and is affected by the hypothesized tradeoff between journey-to-work costs and residential site costs. Based on the discussions by Wingo[19] and Alonso[20] of the negative relationship between income level and population density, it is expected that higher income families will sacrifice propinquity to work place for larger quantities of less expensive residential land at lower population densities.

Individual household preferences which may further influence the amount of residential land consumed are represented in the estimating equations by the sex ratio, number of wage earners in the household, and size of the household.

The sex ratio is expected to set apart the households with limited demand for residential space. Most female workers are single or are members of two-person households. Both single and married working women spend less time in the home than other women and, as a consequence, have less time to enjoy it. In addition, household chores increase with increased space. For all these reasons, the incentive to consume large quantities of space should be quite weak for zones with a low sex ratio.

Families with more than one wage earner, as measured by the labor force participation rate, probably spend less time in the home than do single wage-earner families. Based on this observation, it is likely that they will place less value on the consumption of large quantities of residential land. That is, the labor force participation rate should be positively related to residential space consumption.

Household size is an indicator of the strength of the tie to the home. In families with children, it is less likely that the wife will hold a job outside the home. Larger families probably spend more time in the home, both from choice and from necessity. The home is the center of more social and recreational activities for larger families than for smaller ones. If the children are young, it is necessary that one of the parents remain at home or that a baby sitter be hired. Based on these statements, it is expected that household size will be positively related to residential space consumption.

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[19] Wingo, op. cit.

[20] Alonso, op. cit.

2. Automobile Ownership.

The household income level is expected to be positively related to automobile ownership. An automobile allows more flexibility in departure time and trip destination. It can be assumed that as income increases there is an accompanying increase in the value the individual places on his available time. In addition, with increasing income, the individual may demand greater comfort and privacy.

Level of transit service, which includes frequency of service, seating capacity, and distance to the facility, generally is lower in areas of high income and low population density. Based on this observation, it is hypothesized that level of transit service will be inversely related to automobile ownership.

Preference factors are expected to play a role in the household's decision to own an automobile. Since women earn less than men, they are less likely to own an automobile. Cultural factors probably make it less likely that a female will acquire and operate an automobile. The percentage of women having an operator's license is less than that for men. One and two-member families are more likely to live in high density areas, which are better served by public transportation. Households with more than one wage earner often are smaller and located in high density areas where the need for an automobile is less. From these observations it can be hypothesized that sex ratio, family size, and the labor force participation all will be positively related to automobile ownership.

3. Modal Choice.

Following the household's decision on automobile ownership is the choice of travel mode for the work trip. The measure of modal choice used is percentage of first work trips by each mode in each zone. The modes estimated by equation in the model are automobile, bus, and rapid transit.

People are influenced by many factors in their choice of travel mode. For many purposes, such as visiting friends or weekly grocery shopping, the use of an automobile is almost mandatory. For work trips, however, the choice of mode is dependent upon additional factors. Choice of mode is constrained by level of automobile ownership in the zone. Alternatively, it is likely that the proportion of automobile drivers will be related indirectly to the proportion of transit users in the zone and to the level of transit service. Areas of low population density are expected to be related positively to automobile usage, because transit service, in order to be profitable, must be supported by a concentrated population. Higher income areas should show a positive relationship with automobile usage, even if the effect of automobile ownership is held constant, because persons with lower incomes are more conscious of travel costs and persons with higher incomes generally place a higher value on their time. A high percentage of females in the labor force is expected to be related inversely to automobile use, since fewer females know how to drive, females generally have lower incomes, and they are less likely to own automobiles.

Multiple wage earner households are more likely to use transit, particularly where the work places of the family members are spatially separate. Females are often secondary wage earners in the household, which means they do not have first priority on the automobile.

4. Residential Location.

The final link in the series of equations is residential location, measured by a surrogate for distance, elapsed time between the origin and destination of the trip. Elapsed time includes waiting at transfer point and time spent walking and parking in addition to time in transit. The measure, therefore, includes more than the spatial separation between home and work. Indirectly, it takes into account such factors as the time difference between modes for a given trip, and the relative value of time and money to the individual at a specific time of day.

Travel usually is an intermediate good, the demand for which is linked to some other activity or good. As such, the time in transit may be considered as an integral part of the total good and, by the individual, as either reducing the time spent at the final activity or increasing the total time to be allotted to it. Looked at in this way, travel time is a scarce good, its scarcity being related to the total amount available at any given point in time.

It is hypothesized that there is a tradeoff between location-rent expenditures and transportation expenditures, and that the length of the journey to work is related directly to savings in location rents. These savings are dependent largely upon the level of consumption of residential space. Therefore, it is to be expected that elapsed time will be related positively to the proportion of workers in a zone who reside in single-family housing units.

In many households, the female wage earner is primarily a housewife and only secondarily a member of the labor force. In such cases, it is likely that she will seek employment which is convenient to her home. Because the labor force attachment of women is less than that of men, and they more often belong to families having low space preference and more than one wage-earner, they are expected to make shorter trips than males. It is expected that the converse also is true.

Zones with high proportions of transit riders are expected to have higher mean elapsed times than zones with lower transit usage, since public transit generally is slower and less flexible than the private automobile.

Higher income-level zones seem more likely to have lower elapsed travel times, because more expensive alternative modes are available, and a greater premium is placed on available time. As, for example, public transit becomes relatively less competitive in terms of travel time, demand for its use falls off more quickly among prosperous people, and those with lower incomes generally continue to use transit.

D. THE STUDY AREA.

In order to analyze the results of testing the proposed model, a brief description of the study area, the Village of Skokie, is desirable.

Skokie is located in the northern part of Cook County (see FIGURE 1). It was founded in the 1850's, but remained a small rural community for some time. The rapid population growth of the north shore communities did not extend to Skokie, which was then known as Niles Center. It had the advantage of neither a desirable lakefront location nor transportation lines to Chicago.

With the extension to Dempster Street of rapid transit in 1926 and of the Chicago North Shore and Milwaukee Railroad in 1927, Skokie's first major population growth took place. Between 1920 and 1930, the population increased from 763 to 5,007. Growth halted, however, with the onset of the depression. At the end of the Second World War growth began again. This time, however, growth was not dependent upon the rapid transit system. Service on the elevated line between Evanston and Skokie was discontinued in 1948. Now the automobile was the dominant mode of transportation. Hand-in-hand with the population growth came an increase in industry. These trends continued through the 1950's and into the 1960's. The population of Skokie increased fourfold, from 14,832 to 59,364, in the period between 1950 and 1960.

Skokie is at present and has been for some years a suburb which draws the largest proportion of its labor force from Chicago.[21] Alternatively, the majority of the labor force resident in Skokie is not employed in the suburb.[22] They are largely white-collar workers and are employed in Chicago, from which most came originally.

Table 1 is basically a fact sheet on Skokie taken from the results of the 1960 Census. It indicates that Skokie is in the upper middle class income bracket. This is verified by the median value of owner-occupied, one-unit structures ($27,300). With 74.9 per cent of the male labor force in white collar jobs, 12.6 the median number of years of school, and 47.4 per cent of the families with incomes of $10,000 or more, the upper middle class nature of the suburb is even more apparent.

On the whole, Skokie is a suburb of single-family housing unit structures (75.1 per cent of the housing units are in one-unit structures). This is further emphasized by the fact that 80.6 per cent of the housing units are owner occupied and that the median number of rooms per housing unit is 5.6.

Although the latest population boom was not based on rapid transit, the Chicago Transit Authority recently re-established rapid transit to Dempster Street on an experimental basis. The Skokie Swift, which is financed largely by funds from the Mass Transit Demonstration Act, is an attempt to determine whether public rapid transit really is a feasible alternative mode for a medium density, upper middle income suburban area.

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[21] Cutler, Irving, The Chicago-Milwaukee Corridor: A Geographic Study of Intermetropolitan Coalescence (Studies in Geography, No. 9; Evanston, Ill.: Northwestern University, Department of Geography, 1965), p. 230.

[22] Ibid.

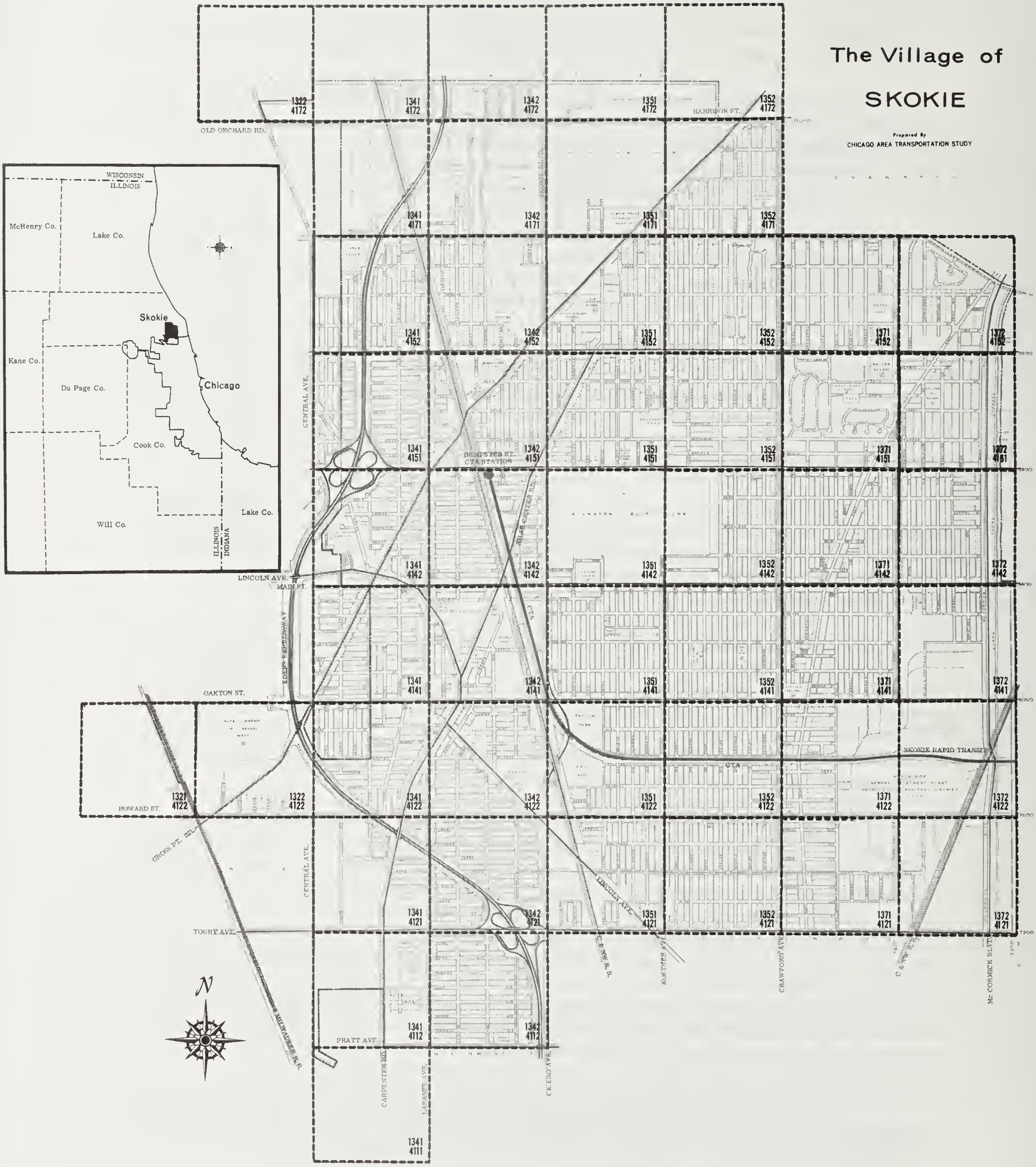
The Village of
SKOKIE
Prepared By
CHICAGO AREA TRANSPORTATION STUDY
WISCONSIN
ILLINOIS
McHenry Co.
Lake Co.
Skokie
Kane Co.
Du Page Co.
Chicago
Cook Co.
Will Co.
Lake Co.
ILLINOIS
INDIANA
OLD ORCHARD RD.
HARRISON ST.
CENTRAL AVE.
DEMPSTER ST. CTA STATION
LINCOLN AVE.
MAIN ST.
EDENS EXPRESSWAY
OAKTON ST.
SKOKIE RAPID TRANSIT
CTA
HOWARD ST.
GROSS PT. RD.
LINCOLN AVE.
TOUHY AVE.
PRATT AVE.
MILWAUKEE R.R.
C. & N.W. R.R.
CARPENTER RD.
LARAMIE AVE.
CICERO AVE.
KOSTNER AVE.
CRAWFORD AVE.
Mc CORMICK BLVD.
N

FIGURE 1

TABLE 1 -- Skokie Characteristics

Population	
1910	568
1920	763
1930	5,007
1940	7,172
1950	14,832
1955	35,800
1960	59,364
1964	67,232
Socio-economic Attributes	
Median school year completed	12.6
% of male workers in white collar occupations	74.9
Median family income	$9,703
% of families with income of $10,000 or more	47.4
% of families with income under $3,000	4.0
Population per household	3.59
% of housing units in 1-unit structures	75.1
% of housing units owner occupied	80.6
Median value, owner housing units (in 1-unit structures, no bus)	$27,300
Median gross rent, renter units	$152
Median number of rooms in housing units	5.6

Sources: United States, Bureau of the Census, County and City Data Book, 1962 (Washington, D. C.: U. S. Government Printing Office, 1962).

Chicago Community Inventory, University of Chicago, Local Community Factbook. Chicago Metropolitan Area, 1960. ed., Evelyn M. Kitagawa and Karl E. Taeuber (Chicago: Chicago Community Inventory, 1963).

With the addition of the Swift, Skokie has a relatively balanced transportation system, which makes it a desirable area in which to test the proposed model. An additional advantage of Skokie as a test area is current data available in a suitable form. However, the relative homogeneity of the area in terms of socio-economic characteristics must be taken into account in the interpretation of results.

PART IV. ANALYSIS AND RESULTS

The following is an attempt to test the Kain model and refine it by using data from Skokie.

A. THE KAIN MODEL.

1. Residential Space Consumption.

The structural equations estimating residential space consumption are shown in Table 2, Equations 1-3. The proportion of variance explained by the first and third equations is quite high, both with (Equations a) and without (Equations b) the inclusion of the density variable. In both equations, the signs of the coefficients are consistent with the hypothesized relationships and with Kain's results with Detroit data.

The second equation, estimating percentage residing in two-family structures, has a very low coefficient of determination on both runs (.161 and .216). None of the variables is statistically significant, and the signs of the variables are the opposite of those obtained in Kain's Detroit study. These results were expected, because two-family structures show characteristics of both single-family and multiple-unit structures. They have, for example, much of the privacy and size of single-family structures, whereas the densities often approach those of multiple-unit buildings.

The price of residential space variable shows the greatest explanatory power. There appears to be little covariance between this variable and any of the other independent variables in the equations.

In Kain's results the income variable showed a low level of statistical significance for which he offered two possible explanations. The space consumption measure, housing-unit type, may not be functionally related to income. The other interpretation, that the definition employed was not an adequate measure of income, seemed to him more plausible. The improved income measure used in this study, although not statistically significant in the space-consumption equations, shows improved power. One possible explanation is that if a functional relationship exists between income and space consumption, it is being obscured by the crudeness of the space-consumption measure. A further consideration must be taken into account. A comparison between the partial and simple correlation coefficients of many of the independent variables in these equations indicates that the degree of covariance between them is considerable.[1] Part of the income effect may be picked up by other variables.

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[1] See Appendix III, Table 6, Regressions 1 and 2.

TABLE 2 -- Summary of Results of First Skokie Regression Analysis

Equations	P	F	Y	S	N	D	B^1	B^2	R^s	A	M^b	Int.	DF	Mult. R^2	Std. Err.
1a.[a]	-.7122 (.0808)[b]	.2036 (.0823)	.1325 (.0736)	.1860 (.1312)	-.1122 (.1353)	...	...	...	...	...	...	119.32	34.	.837	12.58
1b.	-.7772 (.1003)	.2030 (.0820)	.1386 (.0736)	.1343 (.1392)	-.0624 (.1424)	.0957 (.0897)	...	...	...	...	...	129.78	33.	.843	12.55
2a.	.2346 (.1834)	-.0979 (.1868)	-.2770 (.1670)	.3110 (.2979)	-.3280 (.3071)	...	...	...	...	...	...	-0.50	34.	.161	3.74
2b.	.0324 (.2240)	-.0998 (.1833)	-.2580 (.1644)	.1500 (.3111)	-.1732 (.3182	.2979 (.1964)	...	...	...	...	...	3.77	33.	.216	3.67
3a.	.7085 (.0818)	-.1998 (.0833)	-.1009 (.0745)	-.2281 (.1329)	.1526 (.1369)	...	...	...	...	...	...	-19.43	34.	.833	12.33
3b.	.8033 (.0995)	-.1989 (.0814)	-.1098 (.0730)	-.1526 (.1382)	.0801 (.1414)	-.1397 (.0873)	...	...	...	...	...	-34.21	33.	.845	12.06
4a.	...	c	.4995 (.1164)	-.2255 (.1124)	...	...	-.4814 (.1196)	.3775 (.1104)	.2147 (.1176)	...	...	1.10	34.	.656	0.12
4b.	...	c	.4995 (.1165)	-.2416 (.1136)	...	.1131 (.1150)	-.5040 (.1219)	.3526 (.1133)	.2524 (.1238)	...	...	1.09	33.	.666	0.12
5a.	...	...	c	.1869 (.2513)	.3041 (.2423)	...	-.0323 (.1492)	-.2770 (.1364)	.3624 (.1601)	c	...	57.14	34.	.466	7.16
5b.	...	...	c	.2437 (.2584)	.2641 (.2522)	-.1348 (.1443)	c	-.2592 (.1350)	.2929 (.1829)	.0265 (.1522)	...	55.31	33.	.479	7.18
6a.	...	...	c	.2762 (.2678)	-.5724 (.2581)	...	.3808 (.1589)	.1099 (.1453)	-.0481 (.1705)	c	...	6.65	34.	.394	5.42
6b.	...	...	...	.1257 (.2836)	-.5723 (.2769)	.2560 (.1584)	...	.1677 (.1483)	.0598 (.2008)	-.2149 (.1672)	...	21.92	33.	.372	5.60
7a.	-.4687 (.2312)	...	-.0441 (.1247)	.8690 (.2164)	-.1844 (.2269)	...	...	...	-.4436 (.2554)	...	.5108 (.1310)	0.26	34.	.587	0.07
7b.	-.3352 (.2632)	...	-.0591 (.1253)	.9303 (.2237)	-.2282 (.2303)	-.1580 (.1497)	...	...	-.3965 (.2588)	...	.5483 (.1356)	0.17	33.	.601	0.07

[a]Dependent variables of the above equations are:

1. Res Single
2. Res Double
3. Res Multiple
4. Autos Owned
5. Mode Auto
6. Mode Transit
7. Elapsed Time

[b]Coefficients in parentheses are standard errors of regression coefficients.

[c]Deleted by regression.

The family-size variable is statistically significant, but it covaries with other variables in the equations. Neither the sex ratio nor the labor force participation rate is significant. Inclusion of the density measure increases the determinacy of the second estimating equation from .161 to .216. It is possible that a functional relationship does exist, but that it has been obscured because of the crude method by which either the density measure or the space consumption measure was constructed.

2. Automobile Ownership.

Results of the regressions on automobile ownership are shown in Table 2, Equation 4. The explained proportion of the variance is high. There appears to be little advantage to including the density variable, since the coefficient of determination is approximately the same for both runs. The proportion of the variance explained is considerably higher in this study (.656 and .666) than in Kain's Detroit study (.49).

The directions of some of the relationships are not coincident with expectations based on Kain's results. The sex ratio, which is statistically significant, shows an inverse relationship with automobile ownership. A possible explanation is that in a middle-class suburban area, automobile ownership does not vary directly with the percentage of males in the population, but rather with income level. If we may assume that income increases concomitantly with age, ceteris parabus, then the level of automobile ownership might actually decrease with larger proportion male (that is, with increasing age, the probability of a male being married increases).

Bus transit availability shows a negative relationship with automobile ownership. This coincides both with the expected findings and with Kain's results. Rapid transit availability, which was also expected to be negatively related to automobile ownership, has a positive sign and is significant. This result probably reflects the type of community being studied, and the number of transit stops. Few people are close enough to the stops to walk. The relationship between bus availability and automobile ownership is inverse. That is, people are more likely to own automobiles when bus service is not easily accessible. Since parking is available at or near the transit stops, the trip by rapid transit may be viewed as similar to an expressway trip. The transit stop plays the role of an entrance ramp with people entering the stream of inbound city traffic. If considered in this way, automobile ownership should be positively related to the rapid transit availability measure, just as it is to accessibility to expressways.

The family size variable, which was statistically significant in Kain's results, was deleted by regression in the present study. The fact that this variable was unrelated to automobile ownership may be due to its definition. As defined, the variable differentiates between families of two or fewer and of more than two persons. In an area with a relatively high income level, automobile ownership for households of more than one person may be related to number of working members of the household. It may also be affected by status considerations.

Neither residential space consumption nor density is statistically significant in the equations. Both show that they are interrelated with other exogenous variables in the estimating equations.[2]

The income level variable is statistically significant and explains the largest proportion of the variance. This agrees with the findings of numerous transportation studies.

The results of this equation are somewhat questionable. When the simple coefficients of correlation are compared with the partial correlation coefficients, it can be seen that the problem of collinearity is a major one.

3. Modal Choice.

Parts 5 and 6 in Table 2 are the structural equations estimating modal choice. Total variance explained by the independent variables in these equations is low when compared with the results for the other equations comprising the model. The coefficients of determination Kain obtained from Detroit data are much larger.

Each of the variables in the automobile-driver equations varies in the postulated direction and is in agreement with Kain's results. The coefficients of determination are .466 for the first equation and .479 for the second equation, which incorporates the density variable. In the first equation the coefficients of two independent variables, residential space consumption and accessibility to rapid transit are more than twice as large as their standard errors. A comparison of the partial correlations with the simple correlation coefficients indicates that these two variables are the only ones in the equations which are independent and additive. In the second equation none of the variables is significant.

The proportion of total variance explained by the independent variables in the transit-use equations is quite low (.394 and .372). The labor force participation rate and bus accessibility have coefficients more than twice as large as their standard errors in the first equation. Only the labor force participation rate is significant in the second equation. Collinearity is a major problem in both equations.

4. Residential Location.

Equations 7a. and 7b. of Table 2 present the results of regressions on elapsed time, the surrogate for residential location. The coefficients of determination (.587 and .601) indicate a moderate degree of success in selection of the independent variables. Kain's results using Detroit data were slightly better (0.65).

---

[2] See Appendix III, Table 7, Regressions 1 and 2.

The signs of the coefficients agree with those postulated. With one exception, they are also in agreement with Kain's results. The price of residential land, which was positive in Kain's study, has a negative sign in the Skokie results.

The sex ratio appears to be the most important single variable in both equations. Its coefficients are large, statistically significant, and independent. The transit-use variable also is significant. It appears that the insertion of the density variable obscures the effect of price of residential land, which is significant in the first equation, but not in the second.

Residential space consumption, the labor force participation rate, and income level are not statistically significant in the results of either equation. All three exhibit considerable covariance with other variables in the model.

It is apparent that in all of the equations in the model, the problem of interdependent exogenous variables is present. The succeeding section is an attempt to deal with this problem.

B. FACTOR ANALYSIS.

Due to the inconclusive nature of the results obtained by using Kain's model in an unmodified form, and especially because of the presence of collinearity among the exogenous variables, factor analysis was employed to isolate the underlying types of interrelatedness, in order to get a better understanding of the relationships of the model.

Table 3 summarizes the results of the factor analytic solution. Five factors of some recognizable significance have been extracted. Together, they account for about 77 per cent of the common variance.

The first factor, which accounts for 21 per cent of the common variance, depits residential space consumption. It demonstrates that with increasing family size, the proportion of households in single-unit structures also increases. There is a weaker direct association between single-family residences and the automobile ownership, income, and elapsed time measures. Confirming the formulations of the urban land economists and land use theoreticians is the direct relationship of the price of residential land with the multiple-unit structure measure and the converse relationship between the price of residential land and single-family units.

Factor 2 relates to modal choice and explains 15.5 per cent of the common variance. It shows that as population density increases, the decision to use the transit mode increases accordingly. Less closely associated, but showing relationships in the same direction as these two variables, are price of residential land and family size. The choice of the automobile as the transportation mode to work is negatively associated with all the above variables. It is interesting to note that neither of the transit accessibility measures fits this pattern.

TABLE 3 -- Normal Varimax Roated Factors

Variable[a] Name	Loadings[b] on Factor 1	2	3	4	5	Communality
1 Res Single	0.903					0.865
2 Res Double					0.888	0.836
3 Res Multiple	-0.729			-0.377		0.748
4 Auto Ownership	0.422			0.796		0.893
5 Mode Auto		-0.750				0.763
6 Mode Transit		0.881				0.827
7 Time	0.310		0.636			0.558
8 Income	0.336			0.633		0.595
9 Land Value	-0.769	0.303				0.759
10 Sex Ratio			0.920			0.926
11 LF Part	-0.327		0.880			0.897
12 Access Bus				-0.674	0.342	0.639
13 Family Size	0.714	0.434				0.699
14 Access Transit					0.791	0.785
15 Pop Density		0.721	0.309			0.743
Eigenvalue	3.153	2.329	2.303	1.898	1.850	
% of Common Variance	21.0	36.5	51.9	64.6	76.9	

[a]All variables Log. 10 transformed.

[b]Loadings are for a normal varimax rotation after a principal axes factor analysis with all lying in the range 0.30 to -0.30 omitted for clarity.

Employment status is summarized by Factor 3 (15.4 per cent of the variance). It says that zones with larger proportions of workers who are male and workers who are the only wage earners in their households evidence greater spatial separation between home and place of work, as represented by longer elapsed travel times. This finding emphasizes that women have a lower level of labor force attachment.

The fourth factor is an indicator of social status, accounting for 12.7 percent of the common variance. It states that increased income tends to be associated with increased automobile ownership. Zones with larger numbers of multiple-unit structures show higher levels of accessibility to bus transit and show an inverse relationship with income level and automobile ownership.

Accessibility to public transit is the fifth independent factor. It explains 12.3 per cent of the common variance. This is the only factor on which the accessibility of rapid transit has a high loading. Accessibility of bus service, which has a marginal loading on this factor, fits more fully the pattern of the social status factor. The high loading on two-unit housing probably is spurious. The chance element is a valid explanation in this case, because the number of such households in the sample is extremely small.

Using this factor analytic solution as a rationale, it now is possible to proceed with modifications of the Kain model.

C. MODIFICATIONS OF THE KAIN MODEL.

The major reason for simplifying the Kain model is to create a revised model within the outlines of the original which meets the statistical requirements of the multiple regression technique and which at the same time does not distort the theoretical basis which has been presented.

1. Residential Space Consumption.

From the factor analytic solution, the first factor gives an indication of variables which may be used in the estimation of two of the residential space consumption measures, single- and multiple-family residence.

Both land value and family size have high loadings on this first factor. Using the table of correlation coefficients (Table 4) as an adjunct, it can be seen that while there is little correlation between these two variables, both of them evidence strong relationship to single-family residence. Therefore, both may be employed in the new estimating equation for single-family residence. The other variables which loaded above .30 and below -.30 on the first factor may also be considered for possible inclusion in the equation. In all cases these variables either are highly correlated with the two independent variables already included in the revised equation or have a low correlation with single-family residence. One variable, the sex ratio, although it does not appear under the first factor, shows a moderate degree of relationship with single-family residence. It is not related to the other two independent variables and can, therefore, be used in the new estimating equation for single-family residence.

Family size and land value show moderate and high correlations respectively with multiple-unit residence and may be used in that estimating equation. Automobile ownership, which has a moderately high loading on the first factor, has a correlation of .456 with multiple-family residence. Therefore, it, too, is included in the revised equation for estimating multiple-family residence.

The two-family structure estimating equation has been deleted from the revised model for two reasons. Conceptually, two-family housing does not appear to be a distinct and separate measure. It exhibits characteristics of both single- and multiple-unit housing. In addition, the number of sample interviews falling into this category in Skokie was too small to yield statistically significant results.

TABLE 4 -- Residential and Modal Choice

Correlation Coefficients*		R^s	R^2	R^m	A	M^a	M^b	T	Y	P	S	N	B^1	F	B^2	D
1	R^s	1.000														
2	R^2	-0.104	1.000													
3	R^m	-0.657	0.310	1.000												
4	A	0.424	0.103	-0.468	1.000											
5	M^a	0.296	-0.246	-0.516	0.210	1.000										
6	M^b	0.024	0.138	0.133	0.059	-0.617	1.000									
7	T	0.321	0.175	0.063	0.128	0.027	0.132	1.000								
8	Y	0.233	-0.319	-0.456	0.571	0.307	0.061	0.046	1.000							
9	P	-0.688	0.241	0.720	-0.516	-0.385	0.094	-0.195	-0.313	1.000						
10	S	0.383	0.008	-0.176	0.139	0.399	-0.313	0.549	0.129	-0.140	1.000					
11	N	-0.100	0.059	0.159	-0.051	0.066	-0.278	0.319	-0.113	0.186	0.752	1.000				
12	B^1	0.025	0.295	0.200	-0.346	-0.296	0.212	0.025	-0.207	0.243	-0.123	-0.218	1.000			
13	F	0.615	-0.019	-0.374	0.302	-0.141	0.323	0.162	0.175	-0.294	0.031	-0.243	0.098	1.000		
14	B^2	0.134	0.553	0.071	0.109	-0.295	0.161	0.325	-0.284	0.008	0.155	0.151	0.417	0.210	1.000	
15	D	-0.016	0.344	0.128	0.080	-0.406	0.520	0.024	-0.142	0.357	0.137	0.352	0.125	0.200	0.371	1.000

*All variables Log. 10 transformed.

2. Automobile Ownership.

Factor 4 shows that a strong relationship exists between automobile ownership and a group of variables which, in the aggregate, indicate social status. Level of family income has a high loading on this factor, and its coefficient of correlation with automobile ownership also is large (.571). Land value, which does not appear under Factor 4, is highly correlated with automobile ownership and is not strongly related to income level. One other variable, accessibility to bus transit, has a high loading on the fourth factor and shows a moderate degree of correlation with automobile ownership. It is not strongly related to the other two variables, and so, is included in the automobile ownership equation. Multiple-unit residence has been excluded, because it is correlated with both income level and price of residential land.

3. Modal Choice.

Factor 2, relating to modal choice, shows that population density should be a good predictor of both mode auto and mode transit. This is supported by the coefficients of correlation in Table 4. Therefore, the population density variable is included in both modal choice estimating equations.

Although family size has a moderately high loading on Factor 4, it is not related to mode auto. The land value variable, which has a marginal loading on factor, is moderately correlated with mode auto. However, multiple-family residence, for which it is a predictor, shows a stronger relationship to mode auto. Based on this observation, multiple-family residence, rather than price of residential land, is included in the estimating equation. The third variable in the mode auto equation, the sex ratio, is included because its correlation with the dependent variable is relatively high (.399). It is not related to the other two independent variables.

Family size, which was found not to be correlated with mode auto, evidences a stronger relationship with mode transit (correlation coefficient of .323). Since it is not related to population density, it is incorporated into the mode transit estimating equation. The sex ratio, although it does load on Factor 2, is correlated with mode transit and is unrelated to the other independent variables in the new estimating equation.

4. Residential Location.

The third factor, employment status, is the one which incorporates the residential location surrogate, elapsed time. Two variables, the sex ratio and the labor force participation rate, have high loadings on this factor and one variable, population density, is marginal. The sex ratio and the labor force participation rate are highly interrelated. Of the two, the sex ratio correlates more highly with elapsed time and is used in the estimating equation. The population density variable is shown to be unrelated to elapsed time from its very low correlation coefficient (.024). A perusal of the correlation matrix indicates that one other variable, accessibility to rapid transit, is correlated with elapsed time. Because transit access is not related to the sex ratio, it is included in the estimating equation.

5. Revised Equations.

(1) $R_j^s = \alpha_o + \alpha_1 P_j + \alpha_2 F_j + \alpha_3 S_j$

(2) $R_j^m = \alpha_o + \alpha_1 P_j + \alpha_2 F_j + \alpha_3 Y_j$

(3) $R_j^o = 1 - (R_j^s + R_j^m)$

(4) $A_j = \beta_o + \beta_1 P_j + \beta_2 Y_j + \beta_3 B_j^1$

(5) $M_j^a = \gamma_o + \gamma_1 S_j + \gamma_2 D_j + \gamma_3 R_j^m$

(6) $M_j^b = \gamma_o + \gamma_1 F_j + \gamma_2 S_j + \gamma_3 D_j$

(7) $M_j^o = 1 - (M_j^a + M_j^b)$

(8) $T_j = \delta_o + \delta_1 S_j + \delta_2 B_j^2$

D. RESULTS WITH A MODIFIED KAIN MODEL.

Using the revised model specified above, new regression estimates were made. This section reports the results of these estimates.

1. Residential Space Consumption.

In both residential space consumption equations, three exogenous variables are used (see Table 5[3]). The coefficient of determination (R^2) of the single-unit housing equation is .747, as contrasted with the .837 obtained by using the five untransformed variables of Kain's original equation and with Kain's Detroit results (.56). The modified multiple-unit residence equation yields a coefficient of determination of .600. The original equation, using Skokie data, gave an R^2 of .833, and Kain obtained an R^2 of .44 in Detroit. The major differences to be noted, however, are that in the revised equations all but one of the exogenous variables are statistically significant and that all of them are independent.

Within the context of the model, price of residential space is the best predictor in both residential space consumption estimating equations. In both, its regression coefficient is large and its standard error is relatively small, indicating goodness of fit. Its partial correlation is

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[3]The complete results of these regressions are found in Appendix III, Table 6, Regression 3.

TABLE 5 -- Summary of Results of Second Skokie Regression Analysis[a]

Equations	P	F	S	Y	B^1	D	R^m	B^2	Int.	DF	Mult. R^2	Std. Err.
(1.)[b]	-.5131 (.0886)[c]	.4553 (.0877)	.2969 (.0847)	...	...	...	...	...	2.06	36.	0.747	0.19
(2.)	.5986 (.1148)	-.1561 (.1108)	...	-.2417 (.1115)	...	...	...	...	-3.79	36.	0.600	0.49
(3.)	-.3740 (.1280)	...	...	.4544 (.1280)	...	...	...	...	0.16	37.	0.453	0.02
(4.)	...	...	.3855 (.1184)	...	...	-.4078 (.1176)	-.3959 (.1183)	...	1.56	36.	0.524	0.04
(5.)	...	.2295 (.1237)	-.3920 (.1224)	...	...	.5275 (.1248)	...	...	1.75	36.	0.471	0.29
(6.)	...	...	.5113 (.1331)	...	...	...	...	.2456 (.1331)	-0.62	37.	0.361	0.02

[a] All variables Log. 10 transformed.

[b] Dependent variables of the above equations are:

1. Res Single
2. Res Multiple
3. Autos Owned
4. Mode Auto
5. Mode Transit
6. Elapsed Time

[c] Coefficients in parentheses are standard errors of regression coefficients.

higher than that of the other exogenous variables.[4] As hypothesized, the price of residential space is negatively related to single-family residence and is positively related to multiple-unit residence. The findings confirm the statements of urban land economists and human ecologists that the location of types of units is related to land values.

The family size variable is employed in both residential space consumption equations. It varies as hypothesized in both equations, that is, negatively with multiple-unit residence and positively with single-family residence. The standard error of the regression coefficient is large, however, in the multiple-unit residence equation. The explanation of this result probably lies in the way the variable was constructed. Many of the town houses in the survey, even though they are single units by the standard definition, were counted as multiple-unit structures in the survey.[5]

The proportion of workers in a zone who are male (sex ratio) is shown to vary directly with single-family residence. It is not surprising that this relationship should be apparent since there is a concomitant increase in households of more than two persons. Married women with children find it difficult to work outside the home. Because such women spend more time in the home, they would be expected to show a greater preference for residential space.

The level of household income is included as an exogenous variable in the estimation of multiple-unit residence. As postulated, it shows an inverse relationship to multiple-unit residence.

2. Automobile Ownership.

Part 3 of Table 5 shows the results of the revised regression equation estimating automobile ownership using two exogenous variables, income and price of residential land. The coefficient of determination of the revised equation is .453, whereas that of the original equation using Skokie data was .656 and that in Kain's Detroit study was .49.

Level of income is the major explanatory variable in the automobile ownership equation. It shows a positive relationship to the dependent variable and is statistically significant and orthogonal. The fact that the sign is positive supports the postulate that with increased income an individual can and will demand greater comfort and privacy and that he places a greater value on the time available to him.

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[4]See Appendix III, Table 6, Regression 3.

[5]Town houses which do not face the street have the same street address number as the neighboring attached structures, but with a letter following the number to designate location within the complex. The survey sample was drawn from a street address directory in which these letter designations were seldom included. Therefore, to facilitate interval checking (see Appendix II), such town houses were treated as one unit within a multiple-unit structure.

A second significant variable, the price of residential land, evidences a negative relationship with automobile ownership. This agrees with the hypothesis that since land values are negatively related to single-family residence and since people residing in single-family residences have a number of reasons (such as lack of transit accessibility and number of persons needing transportation) for finding an automobile highly desirable, residential land values will show a negative relationship with automobile ownership.

3. Modal Choice.

The modal choice decision is estimated by Equations 4 and 5 in Table 5. In each equation, three exogenous variables are employed to explain the variance of the dependent variable. The automobile mode equation yields a coefficient of determination of .524. This may be compared with the R^2 of .466 obtained using the Kain model in an unmodified form and with Kain's results in Detroit (.82). The three variables which are included in this modified equation are the sex ratio, population density, and single-family residence. All are statistically significant. However, population density is not independent of the other exogenous variables.[6] In estimating the choice of transit as mode, three variables, population density, the sex ratio, and family size, give a coefficient of determination of .471, compared with .394 for the original Skokie results and .83 in Detroit.

Population density is a bipolar variable, that is, it is inversely related to mode auto and positively related to mode transit. This supports the original hypothesis that in areas of low population densities, automobile usage will be higher because transit service, which depends upon a concentrated population to operate economically, will be poorer. With increasing densities, transit service will tend to improve, and as a result, transit usage will increase.

The sign of the regression coefficient of the sex ratio variable is positive in the auto usage equation and negative for mode transit. This was expected because more men than women know how to drive, men have higher incomes, and men are more likely to own and have access to an automobile.

Although single family residence and low population densities are related, this relationship probably is not a linear one. Therefore, in addition to the reasoning applied to the relationship between population density and mode auto, a related reason can be given for the inverse relationship of single family residence to mode auto. The single family residence measure combines the effects of higher income levels and increased family size.

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[6]Note R^2 with rest of model in Choice Mode--Automobile, Regression 3 of Table 8, Appendix III.

The third variable in the transit usage equation, family size, is orthogonal, but of marginal statistical significance. The sign of the regression coefficient is positive, which may mean that in larger families with more than one wage earner, one or more of the workers uses transit.

4. Residential Location.

The residential location equation, employing two exogenous variables, is given in Table 5, Equation 6. The coefficient of determination (.391) is low compared with that of the original equation in Skokie (.587) and in Detroit (.65). Both variables are, however, independent and additive.

The sex ratio is the major exogenous variable. Its positive relationship to elapsed travel time, the residential location surrogate, agrees with the hypothesis that the labor force attachment of women is relatively weak. Many women, because they are secondary wage earners, seek employment convenient to their homes, which would explain their shorter work trips.

The other independent variable, accessibility to rapid transit, is of marginal significance. The positive sign of the regression coefficient, however, coincides with the expected relationship. Rapid transit generally is a slower mode than automobile.

PART V. CONCLUSION

A. DIFFERENCES IN PERFORMANCE OF THE MODELS.

1. The Original Model: Skokie Versus Detroit.

In comparing the results of the original model in Skokie and Detroit, several differences may be noted. The residential space consumption and automobile ownership equations exhibit noticeably higher coefficients of determination in the Skokie results.[1] A great deal of the improvement may be attributed to the more accurate way in which the price of residential space is defined in this study. Improvement in the coefficient of determination of the automobile ownership equation can also be attributed to the use of a more discriminating measure for one of the independent variables, in this case, level of household income.

The lower coefficients of determination obtained for the modal choice and residential location equations cannot be explained in terms of the definition of variables. One possible explanation for this result lies in the problem of "modifiable units" discussed by Duncan.[2] Basically, the problem lies in the fact that correlation and regression results from one set of areal units will generally differ from those obtained from another set of units. The Duncan book refers to McCarty, et al[3] who discuss the problem of "scale":

> "In geographic investigation it is apparent that conclusions derived from studies made at one scale should not be expected to apply to problems whose data are expressed at other scales. Every change in scale will bring about the statement of a new problem, and there is no basis for presuming that association existing at one scale will also exist at another."

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[1] The one exception is the two-unit housing equation. It has already been pointed out, however, that because of small sample size this variable cannot yield statistically significant results.

[2] Duncan, O. D., Cuzzort, R. P., and Duncan, B., Statistical Geography (Glencoe, Illinois: The Free Press, 1961), pp. 109-111.

[3] McCarty, H. H., Hook, J. C., and Knos, D. S., The Measurement of Association in Industrial Geography (Iowa City: State University of Iowa, Department of Geography, 1956), p. 16.

The modifiable unit explanation appears to be relevant to the present comparison of results in two ways. Skokie, as a suburb of Chicago, encompasses a relatively small proportion of the total Chicago Metropolitan Area. Kain's results are reported for the whole metropolitan area of Detroit. The second difference lies in the areal units of analysis. In general, the Detroit Traffic Zones are considerably larger than the quarter-section units employed in Skokie. The power performance of the modal choice and residential location equations is thus to be found in the greater role local variability plays in the results.

2. Skokie: The Original Versus the Modified Model.

Results of the two models employed in Skokie can be compared directly because data and analysis units are defined in the same way and are at the same levels of aggregation.

Decreasing the number of independent variables while normalizing the data did not decrease markedly the proportion of the variance explained. In fact, in two cases, the mode auto and mode transit equation, the coefficients of determination from the modified equations were higher than in Kain's original form.

The important difference between these two sets of equations, however, is that the variables in the modified equations meet the statistical requirements of the multiple regression model. They are independent, additive, and normally distributed. In addition, all are statistically significant. Moreover, with the same explanatory power, the modified set is simpler.

B. VALUE OF THE STUDY.

The ability of the model to explain a considerable proportion of the variation in behavior based on quantifiable social and economic variables indicates that the nonquantifiable factor of "sentiment" discussed by Firey, although it may be present, is not a major contributing variable to explanation, unless this "sentiment" is an outward expression of the social and economic characteristics themselves.

This study, by focusing on specific relationships which underlie the behavior of consumers vis à vis their choices of travel mode and residence, is a step in the direction of "explaining" such behavior. The specific model in modified form is of importance to transportation planners who need adequately tested models. It gives them a more precise planning tool.

APPENDIX I -- THE SKOKIE STUDY

APPENDIX II -- THE DATA

APPENDIX III -- STATISTICS FROM REGRESSIONS

A. THE SKOKIE DEMONSTRATION PROJECT.

In 1963, application was made by the Chicago Transit Authority to the Housing and Home Finance Agency for a federal grant to conduct a mass transit demonstration project under the terms of the Mass Transit Demonstration Grant Program of 1963. The objectives of this study were:

(1) To determine the effectiveness and economic feasibility of linking a fast-growing, medium-density suburban area with the central city by means of a high-speed rail rapid transit extension coordinated with suburban buses and with the central city's extensive transit network;

(2) To develop through surveys and studies criteria and guidelines useful nationally to public officials, planners, transit operators and others in determining whether service of this type should and can be provided in large metropolitan areas.[1]

Data collection and analysis on a number of sub-studies has been undertaken by a number of agencies in the Chicago metropolitan area. The Chicago Area Transportation Study was responsible for an origin and destination survey of transit users and a home interview study, and coding, data processing, and analysis of the data obtained.

The chief source of data for this study was the Skokie Home Interview Survey.

B. SKOKIE HOME INTERVIEW STUDY.

Whereas the origin and destination survey is based on a sample of transit users, the home interview study is composed of a sample of housing units in the study area.

A stratified random sample of housing units in Skokie was obtained from the North Suburban Street Address Directory.[2] In this directory all listed telephones are arranged alphabetically by street name and numerically by address. From the Skokie listings, every eleventh entry was entered in the sample. Every twenty-second listing was also included in the sample from the portion of Morton Grove east of Harlem Avenue. The Morton Grove interviews were not included in this study. The total size of the Skokie sample was 1, 793 housing units.

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[1]Chicago Transit Authority, Skokie, Illinois, Demonstration Project. Application for Federal Aid (Chicago: author, December 17, 1963), Exhibit A: General Description.

[2]North Suburban Street Address Directory (Chicago: Reuben H. Donnelly Corp., 1964).

An interval check method was worked out in which the succeeding telephone listing on the same side of the street as the interviewed housing unit was used as a control. If there was a housing unit between the interview and the control housing units, it was entered on a separate list. All unlisted housing units in the structure in which the interviewed housing unit was located were also included on this list. From this listing, a sample of unlisted housing units was drawn at a rate of one in three. The total number of unlisted housing units was 193.

A. THE SUBSAMPLE.

The data used in this study were obtained from the Skokie home survey conducted by the Chicago Area Transportation Study in the Autumn of 1964. Information was entered on three forms, two of which were employed in this study.

The housing unit summary (see FIGURE 2) contains information about the residential location and socio-economic characteristics of the family. Travel characteristics of the household for a twenty-four hour weekday period are contained on the internal trip report (see FIGURE 3).

The subsample used in the study included all "legitimate home to work trips." "Legitimate work trips," as defined by Kain, include only regular daily trips from place of residence to a fixed work place. In order to achieve this objective, all first trips to work were included, and trips from work to work and from school to work were excluded.

Trips from shopping and from eat meal to work were included if they were the second trip by the tripmaker that day. From serve passenger to work trips were included if they were the second, third, or fourth trips of the day. All trips to or from personal business or social recreation were rejected.

Occupation code was scanned, and those persons coded housewife, student, unemployed, and retired were omitted.

The subsample of "legitimate work trips" for employed persons included 1,436 households. All of these were from the ten per cent sample of Skokie housing units. Morton Grove housing units, which were sampled at a five percent rate, were excluded.

B. FORM OF THE DATA.

1. Price of Residential Space.

Front-foot land value figures for each interviewed housing unit were taken from Olcott's Land Values Blue Book of Chicago.[1] These were recorded on the original housing-unit summary cards, and the mean value was taken for each zone.

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[1] Olcott's Land Values Blue Book of Chicago, 1964 (Chicago: Scribner and Co., 1964).

FORM IV-15-8/64

FIGURE 2

MASS TRANSIT DEMONSTRATION PROJECT

HOUSING UNIT SUMMARY

CONFIDENTIAL – THE INFORMATION OBTAINED IN THIS SURVEY WILL BE ACCORDED CONFIDENTIAL TREATMENT. INDIVIDUAL REPORTS WILL BE USED FOR STATISTICAL PURPOSES ONLY

CARD NO. 3 8 6

SECTION I

A. SAMPLE NO ________ TRAVEL DATE ________ DAY ________

B. INTERVIEW ADDRESS ________ TEL. NO. ________

C. STRUCTURE TYPE 1. SINGLE UNIT 2. TWO UNITS 3. MULTI UNIT 4. HOTEL 5. MOTEL OR CABIN COURT 6. ROOMING HOUSE 7. INSTITUTION 8. TRAILER 9. OTHER (SPECIFY BELOW)

D. WAS THIS STRUCTURE BUILT AFTER APRIL 1, 1960 ? 1. ☐ YES 2. ☐ NO

E. TYPE OF LIVING QUARTERS AND OCCUPANCY: 1. HOUSING UNIT 2. GROUP QUARTERS 3. SPECIAL HOUSING UNIT

SECTION II

A. HOW MANY PASSENGER CARS ARE OWNED AND/OR GARAGED AT THIS ADDRESS ? (INCLUDE GOVERNMENT AND COMPANY CARS)

B. MAKE, YEAR MODEL, 1. ________ 2. ________ 3. ________ 4. ________

C. HOW MANY PERSONS LIVE IN THIS HOUSEHOLD ? ________

D. HOW MANY PERSONS 5 YEARS OF AGE AND OVER LIVE IN THIS HOUSEHOLD ? ________

E. HOW MANY OUT OF AREA VISITORS 5 YEARS OF AGE AND OVER STAYED IN THIS HOUSEHOLD OVERNIGHT ? ________

F. INCOME OF HOUSEHOLD? ________

SECTION III

A. DATA FOR PERSONS 5 YEARS AND OVER (INCLUDING RESIDENTS AND OUT OF AREA VISITORS)

1 PERSON NUMBER	2 SEX AND RACE	3 AGE	4 PERSON IDENTIFICATION (RELATIONSHIP TO HEAD)	5 DRIVE A CAR? (✓) YES	NO	6 OCCUPATION	CODE	CODE	7 INDUSTRY	8 MADE TRIPS (✓) YES	NO	NOT KNOWN	9 DID YOU MAKE ANY TRIPS WHILE AT WORK? YES	NO	NOT KNOWN	10 DID YOU WALK TO WORK ON TRAVEL DATE? YES	NO
*																	
1	M F W O		HEAD														
2	M F W O																
3	M F W O																
4	M F W O																
5	M F W O																
6	M F W O																
7	M F W O																
8	M F W O																
9	M F W O																
10	M F W O																

* CIRCLE LINE NUMBER OF EACH PERSON INTERVIEWED

SECTION IV

A. REASONS FOR NON-INTERVIEW OR INCOMPLETE REPORT

B. NO. OF TRIPS REPORTED AT THIS ADDRESS — TOTAL TRIPS ( )

— AUTO DRIVER TRIPS ( )

1. NO. OF PERSONS 5 YEARS OF AGE AND OVER MAKING TRIPS ( )

2. NO. OF PERSONS 5 YEARS OF AGE AND OVER MAKING NO TRIPS ( )

3. NO. OF PERSONS 5 YEARS OF AGE AND OVER WITH TRIPS UNKNOWN ( )

C. NO. OF PERSONS 16 YEARS OF AGE OR OVER ( )

1. NO. OF PERSONS 16 YEARS OF AGE OR OVER THAT DRIVE A CAR ( )

D. (OFFICE USE ONLY) COMPLETED OR NON INTERVIEW CODE ( )

SECTION V ADMINISTRATIVE RECORD

INTERVIEWER ________

DATE REPORT COMPLETED ________

CALLS MADE

DATE	TIME	RESULT

NOTES, APPOINTMENTS, ETC.

SUPERVISOR'S COMMENTS

EDITOR ________ DATE ________ PASS FAIL

CODER ________ DATE ________ PASS FAIL

FOLLOWUP ________ DATE ________

RESULT ________

CODING CHECK ________ DATE ________

REMARKS

FIGURE 3

FORM IV - 16 8/64

MASS TRANSIT DEMONSTRATION PROJECT INTERNAL TRIP REPORT

CARD NO. 3 8 7

SAMPLE NUMBER | DATE

A	B	C	D	E	F	G	H		J		K		L	M	N	O	P
SEX AND RACE	AGE	OCC. AND IND.	PERSON NUMBER	TRIP NUMBER	WHERE DID THIS TRIP BEGIN ? (ORIGIN)	WHERE DID THIS TRIP END? (DESTINATION)	TRIP PURPOSE		LAND USE AT		TIME OF		MODE OF TRAVEL	AUTO-PASSENGERS (INCL. DRIVER)	WAS CTA EXTENTION USED	AUTO AVAILABLE	CAR POOL
							FROM	TO	ORIGIN	DESTINATION	START	ARRIVAL					
					STREET ADDRESS CITY	STREET ADDRESS CITY					AM PM	AM PM					
					STREET ADDRESS CITY	STREET ADDRESS CITY					AM PM	AM PM					
					STREET ADDRESS CITY	STREET ADDRESS CITY					AM PM	AM PM					
					STREET ADDRESS CITY	STREET ADDRESS CITY					AM PM	AM PM					
					STREET ADDRESS CITY	STREET ADDRESS CITY					AM PM	AM PM					
					STREET ADDRESS CITY	STREET ADDRESS CITY					AM PM	AM PM					

(A) SEX + RACE	DRIVER	NON-DRIVER
MALE, WHITE	1	5
FEMALE, WHITE	2	6
MALE, OTHER	3	7
FEMALE, OTHER	4	8

(H) TRIP PURPOSE
1. HOME
2. WORK
3. SHOP
4. SCHOOL
5. SOCIAL-RECREATION
6. EAT MEAL
7. PERSONAL BUSINESS
8. SERVE PASSENGER
9. CHANGE MODE

(L) MODE OF TRAVEL
1. AUTO DRIVER
2. AUTO PASSENGER
3. RAILROAD
4. BUS
5. TAXI PASSENGER
6. TRUCK PASSENGER
7. SCHOOL BUS
8. WALKED TO WORK
9. RAPID TRANSIT

SHEET ____ OF ____ SHEETS

The figures listed by block-face in Olcott's Blue Book

> ". . . are the unit of values per front-foot, for inside lots not coming under the corner influence in every block . . . The unit used is for lots 125 feet in depth . . . The valuations . . . are arrived at by making a careful survey each year of the whole city and suburbs, interviewing local dealers for data on sales, asking prices and rentals in their neighborhood. Occupancy and collections are also inquired into. In the office of the publication, files are compiled of transfers and advertised prices and all other information obtainable as to the trend of the market. The valuations may be said to be quotations of land values rather than estimates of them."[2]

Land values were obtained for all housing units, with the exception of those located in buildings in commercially zoned areas. In these cases the residential land use was considered to be secondary.

2. Income.

The income measure used in the analysis was median household income for each analysis zone. Household income, rather than income of head of household, was chosen because it is a measure defined for the total decision-making unit.

The data used were those obtained from the home interviews of the Skokie home survey. Of the 1,436 households in the subsample used in the study, 83 per cent answered the income question. A selector card was used in the survey, and the response was the letter of one income group of the six into which the family income fell. These groups were:

a. Less than $ 5,000
b. $5,000 to $ 7,000
c. $7,000 to $ 9,000
d. $9,000 to $12,000
e. $12,000 to $15,000
f. $15,000 and over

Using the distribution plotted for these six income classes, a modified distribution was derived with intervals of $1,000 by means of extrapolation. This modified distribution for the whole of Skokie was compared with the distribution of the 1960 United States Census of Population income data for the village. It was found that the shape of the

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[2] Ibid., p. A26.

distributions was similar. The major difference between the two was the movement upward of the 1964 distribution. Because of the similarity between the distributions, the housing units with unreported incomes were distributed for each zone in the same proportion as the reported incomes in the zone.

The median figure for each zone was determined by arranging the households by income class and determining the median household. The median household income was assumed to be the same proportion of the distance through the income bracket as the median household was through its income group. That is, if the median household was the fifth household of the twenty households in the $7, 000 to $9, 000 income bracket, the median income for that zone would be one-fourth of the distance through the bracket, or $7, 500.

The measure used in the study is a considerable improvement over the one used by Kain. He employed the median occupational earning for each worker's occupation and sex, which he loosely interpreted as "the average wage and salary income of primary wage earners."[3] His measure falls short of the measure used in this study in two ways:

1. The basic income estimate from which it is constructed is crude (a one-digit occupational code).
2. It measures only the incomes of male heads of household.

3. Space Preference.

The sex ratio is defined as the percentage of each zone's workers who are male.

The labor force participation rate is the proportion of the employed persons in each zone who are members of a household with a single wage earner.

The measure of family size used is the proportion of each zone's workers who belong to families having more than two members.

4. Transit Variables.

The bus accessibility measure in the study is based on number of coaches passing through or touching on a quarter section zone during a twenty-four hour weekday period and weighted by an approximate measure of the route's distance from the centroid of the zone. Specifically, the following cases were dealt with (see FIGURE 4):

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[3] Kain, John F., "The Journey to Work as a Determinant of Residential Location" (unpublished Ph.D. dissertation, Dept. of Economics, University of California, 1961), p. 262.

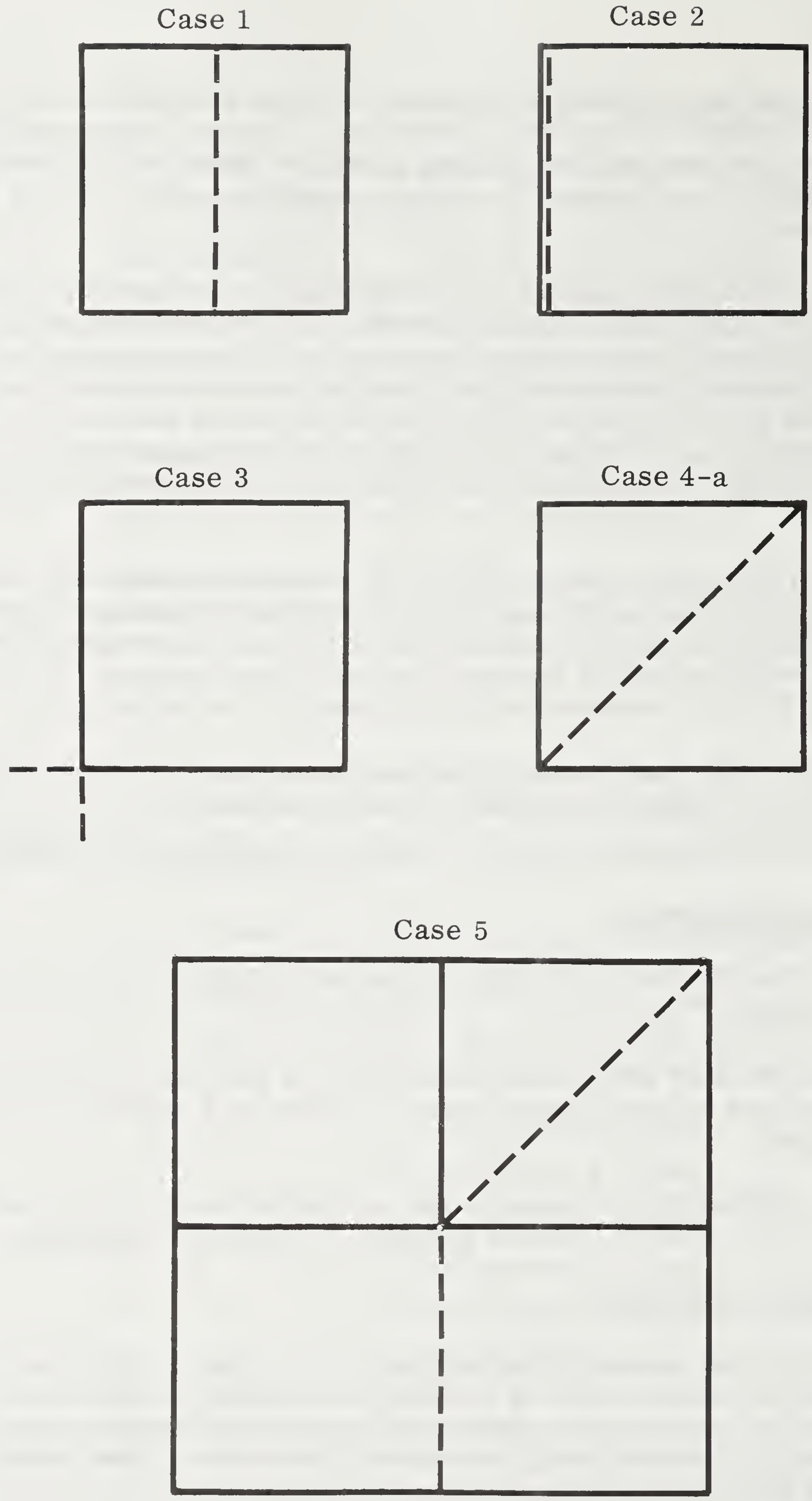

FIGURE 4

BUS ACCESSIBILITY CASES

Case 1. If a center route, $B_j^1 = \frac{c}{1}$

Case 2. If an edge route, $B_j^1 = \frac{c}{2}$

Case 3. If a corner route, $B_j^1 = \frac{c}{4}$

Case 4. If a diagonal route,

a. for the zone in which it is contained, $B_j^1 = \frac{c}{1}$

b. for the zones on which the route touches a corner, the corner route method is used (Case 3).

Case 5. If a diagonal route jogs to follow a zonal boundary, treat the zones as indicated in Case 5 of FIGURE 4.

In all of the above cases, c = number of coaches in a twenty-four hour weekday period passing through or touching on a zone. Routes following a zonal boundary are included in the indexes for both zones that they touch. Corner routes are treated in a similar manner.

The measure of rapid transit accessibility used in the study employed distance from transit stop and seating capacity. For each zone the index $B_j^2 = \frac{s_i}{d_i}$ was used in which:

s_i = the seating capacity of the coaches passing through a transit stop,

d_i = the distance from the centroid of a zone to a transit stop.

B_j^2 is a compound index, composed of measures for three transit stops:

a. The Skokie Swift Dempster Street Terminal,

b. The Howard Street elevated terminal,

c. The nearest stop on the Evanston elevated line.

Ground, not airline, distance was measured to each of the transit stops. Diagonal street distances were excluded from the measurements. For each zone, each of the three distances (d_i) was divided into the seating capacity (s_i) of the trains leaving the stop in one twenty-four hour weekday. These three simple indexes then were summed to give a composite measure of transit accessibility for each analysis zone.

5. Residential Space Consumption.

Percentages of a zone's interviewed housing units living in each type of housing unit was the indicator of residential space consumption employed in this study and in Kain's study in Detroit. In both studies, four types of structures were recognized;

a. Single family housing units,

b. Two-family housing units,

c. Multiple family housing units,

d. Other types of housing units, i. e., rooming houses, hotels, trailers.

6. Automobile Ownership.

The automobile ownership variable in this study was measured by mean automobile ownership per household by zone.

7. Modal Choice.

Two estimating equations and one identity were used to define modal choice. The two equations estimate:

a. The proportion of the zone's workers who drive automobiles,

b. The proportion who ride transit to work.

8. Residential Location.

Mean elapsed time per zone between origin and destination was the surrogate of distance employed in the study.

APPENDIX III -- STATISTICS FROM REGRESSIONS

TABLE 6 -- Residential Space Consumption

Single Family Residential

	Regression 1					Regression 2						Regression 3		
Dependent Variable					1 Res Single						1 Res Single			1 Res Single
Multiple R					0.915						0.918			0.864
F					34.97						29.50			35.41
Degrees of Freedom (N-K-1)					34.						33.			36.
Multiple R Squ.					0.837						0.843			0.747
Intercept A					119.316935						129.780249			2.058203
Std. Error of Estimate					12.581368						12.547323			0.193026
Independent Variables	P	F	Y	S	N	P	F	Y	D	S	N	P	F	S
Partial R	-0.834	0.391	0.295	0.236	-0.141	-0.803	0.396	0.311	0.186	0.166	-0.076	-0.695	0.654	0.505
F	77.74	6.13	3.24	2.01	0.69	60.10	6.12	3.55	1.18	0.93	0.19	33.57	26.93	12.29
Simple Correlations	-0.869	0.508	0.411	0.258	-0.114	-0.869	0.508	0.411	-0.355	0.258	-0.114	-0.688	0.615	0.383
R^2 with Rest of Model	0.266	0.293	0.115	0.722	0.738	0.526	0.293	0.120	0.384	0.754	0.765	0.104	0.086	0.020
Standardized B*	-0.7122	0.2036	0.1325	0.1860	-0.1122	-0.7772	0.2030	0.1386	0.0957	0.1343	-0.0624	-0.5131	0.4553	0.2969
Regression Error	0.0808	0.0823	0.0736	0.1312	0.1353	0.1003	0.0820	0.0736	0.0879	0.1392	0.1424	0.0886	0.0877	0.0847
Metric B	-0.574376	0.363487	0.001330	0.513826	-0.196758	-0.626758	0.362364	0.001391	0.000719	0.370973	-0.109531	-2.619930	1.416752	1.647690
Regression Error	0.065143	0.146855	0.000739	0.362481	0.237298	0.080850	0.146461	0.000739	0.000661	0.384587	0.249856	0.452199	0.272992	0.459951

TABLE 6 -- (Continued)

Two-Family Residential

	Regression 1					Regression 2					
Dependent Variable					2 Res Double						2 Res Double
Multiple R					0.401						0.464
F					1.31						1.51
Degrees of Freedom (N-K-1)					34.						33.
Multiple R Squ.					0.161						0.216
Intercept A					-0.499840						3.767403
Std. Error of Estimate					3.742021						3.672458
Independent Variables	Y	P	N	S	F	Y	D	F	N	S	P
Partial R	-0.274	0.214	-0.180	0.176	-0.090	-0.264	0.255	-0.094	-0.094	0.084	0.025
F	2.75	1.64	1.14	1.09	0.27	2.46	2.30	0.30	0.30	0.23	0.02
Simple Correlations	-0.323	0.252	-0.039	-0.039	-0.121	-0.323	0.374	-0.121	-0.039	-0.039	0.252
R^2 with Rest of Model	0.115	0.266	0.738	0.722	0.293	0.120	0.384	0.293	0.765	0.754	0.526
Standardized B*	-0.2770	0.2346	-0:3280	0.3110	-0.0979	-0.2580	0.2979	-0.0998	-0.1732	0.1500	0.0324
Regression Error	0.1670	0.1834	0.3071	0.2979	0.1868	0.1644	0.1964	0.1833	0.3182	0.3111	0.2240
Metric B	-0.000364	0.024789	-0.075386	0.112542	-0.022888	-0.000339	0.000293	-0.023346	-0.039812	0.054282	0.003426
Regression Error	0.000220	0.019375	0.070578	0.107811	0.043678	0.000216	0.000193	0.042868	0.073130	0.112564	0.023664

TABLE 6 -- (Continued)

Multiple Family Residential

	Regression 1	Regression 2	Regression 3
Dependent Variable	3 Res Multiple	3 Res Multiple	3 Res Multiple
Multiple R	0. 913	0. 919	0. 774
F	33. 96	30. 03	17. 97
Degrees of Freedom (N-K-1)	34.	33.	36.
Multiple R Squ.	0. 833	0. 845	0. 600
Intercept A	-19. 431558	-34. 213093	-3. 787715
Std. Error of Estimate	12. 329359	12. 055675	0. 492629

Independent Variables	Regression 1					Regression 2						Regression 3		
	P	F	S	Y	N	P	F	D	Y	S	N	P	Y	F
Partial R	0. 830	-0. 380	-0. 282	-0. 226	0. 188	0. 815	-0. 391	-0. 268	-0. 263	-0. 189	0. 098	0. 656	-0. 340	-0. 229
F	75. 08	5. 76	2. 95	1. 84	1. 24	65. 18	5. 96	2. 56	2. 26	1. 22	0. 32	27. 17	4. 70	1. 99
Simple Correlations	0. 867	-0. 510	-0. 262	-0. 384	0. 122	0. 867	-0. 510	0. 319	-0. 384	-0. 262	0. 122	0. 720	-0. 456	-0. 374
R^2 with Rest of Model	0. 266	0. 293	0. 722	0. 115	0. 738	0. 526	0. 293	0. 384	0. 120	0. 754	0. 765	0. 157	0. 105	0. 094
Standardized B*	0. 7085	-0. 1998	-0. 2281	-0. 1009	0. 1526	0. 8033	-0. 1989	-0. 1397	-0. 1098	-0. 1526	0. 0801	0. 5986	-0. 2417	-0. 1561
Regression Error	0. 0818	0. 0833	0. 1329	0. 0745	0. 1369	0. 0995	0. 0814	0. 0873	0. 0730	0. 1382	0. 1414	0. 1148	0. 1115	0. 1108
Metric B	0. 553142	-0. 345252	-0. 609812	-0. 000981	0. 259171	0. 627143	-0. 343666	-0. 001016	-0. 001067	-0. 408002	0. 135946	6. 202338	-1. 902171	-0. 985767
Regression Error	0. 063838	0. 143914	0. 355221	0. 000724	0. 232545	0. 077682	0. 140723	0. 000635	0. 000710	0. 369518	0. 240066	1. 189914	0. 877236	0. 699596

TABLE 7 -- Automobile Ownership

	Regression 1	Regression 2	Regression 3
Dependent Variable	4 Autos Owned	4 Autos Owned	4 Autos Owned
Multiple R	0. 810	0. 816	0. 673
F	12. 96	10. 95	15. 30
Degrees of Freedom (N-K-1)	34.	33.	37.
Multiple R Squ.	0. 656	0. 666	0. 453
Intercept A	1. 095216	1. 093908	0. 156317
Std. Error of Estimate	0. 115274	0. 115328	0. 024387

Independent Variables	Regression 1: Y	Regression 1 (F deleted by regression): B^1	Regression 1 (F deleted by regression): B^2	Regression 1 (F deleted by regression): S	Regression 1: R^s	Regression 2: Y	Regression 2: B^1	Regression 2: B^2	Regression 2: S	Regression 2: R^s	Regression 2: D	Regression 3: Y	Regression 3: P
Partial R	0. 593	-0. 568	0. 506	-0. 325	0. 299	0. 595	-0. 584	0. 476	-0. 347	0. 335	0. 169	0. 504	-0. 433
F	18. 41	16. 20	11. 69	4. 02	3. 33	18. 08	17. 11	9. 68	4. 52	4. 16	0. 97	12. 59	8. 53
Simple Correlations	0. 570	-0. 511	0. 108	0. 134	0. 534	0. 570	-0. 511	0. 108	0. 134	0. 534	-0. 131	0. 571	-0. 516
R^2 with Rest of Model	0. 253	0. 292	0. 170	0. 199	0. 268	0. 254	0. 318	0. 211	0. 216	0. 338	0. 233	0. 098	0. 098
Standardized B*	0. 4995	-0. 4114	0. 3775	-0. 2255	0. 2147	0. 4955	-0. 5040	0. 3526	-0. 2416	0. 1131	0. 4544	0. 4544	-0. 3740
Regression Error	0. 1164	0. 1196	0. 1104	0. 1124	0. 1176	0. 1165	0. 1219	0. 1133	0. 1136	0. 1238	0. 1150	0. 1280	0. 1280
Metric B	0. 000032	-0. 000011	0. 000008	-0. 003924	0. 001353	0. 000031	-0. 000012	0. 000007	-0. 004205	0. 001591	0. 000005	0. 153457	-0. 166347
Regression Error	0. 000007	0. 000003	0. 000002	0. 001956	0. 000741	0. 000007	0. 000003	0. 000002	0. 001978	0. 000780	0. 000005	0. 043244	0. 056947

TABLE 8 -- Choice of Mode

Choice Mode--Automobile

	Regression 1	Regression 2	Regression 3
Dependent Variable	5 Mode Auto	5 Mode Auto	5 Mode Auto
Multiple R	0. 682	0. 692	0. 724
F	5. 93	5. 06	13. 19
Degrees of Freedom (N-K-1)	34.	33.	36.
Multiple R Squ.	0. 466	0. 479	0. 524
Intercept A	57. 136922	55. 314092	1. 558654
Std. Error of Estimate	7. 163385	7. 178636	0. 037078

Independent Variables	Regression 1					Regression 2						Regression 3		
		(A & Y deleted by regression)					(B^1 & Y deleted by regression)							
	R^s	B^2	N	S	B^1	B^2	R^s	N	S	D	A	D	R^m	S
Partial R	0. 362	-0. 329	0. 210	0. 127	-0. 037	-0. 317	0. 269	0. 179	0. 162	-0. 161	0. 030	-0. 500	-0. 487	0. 477
F	5. 13	4. 12	1. 58	0. 55	0. 05	3. 68	2. 57	1. 10	0. 89	0. 87	0. 03	12. 03	11. 20	10. 59
Simple Correlations	0. 388	-0. 300	0. 442	0. 509	-0. 386	-0. 300	0. 388	0. 442	0. 509	-0. 317	0. 164	-0. 406	-0. 516	0. 399
R^2 with Rest of Model	0. 387	0. 155	0. 732	0. 751	0. 294	0. 135	0. 528	0. 752	0. 764	0. 242	0. 319	0. 483	0. 055	0. 057
Standardized B*	0. 3624	-0. 2770	0. 3041	0. 1869	-0. 0323	-0. 2592	0. 2929	0. 2641	0. 2437	-0. 1348	0. 0265	-0. 4078	-0. 3959	0. 3855
Regression Error	0. 1601	0. 1364	0. 2423	0. 2513	0. 1492	0. 1350	0. 1829	0. 2522	0. 2584	0. 1443	0. 1522	0. 1176	0. 1183	0. 1184
Metric B	0. 113910	-0. 000277	0. 167686	0. 162242	-0. 000037	-0. 000259	0. 092050	0. 145583	0. 211588	-0. 000318	1. 320111	-0. 059606	-0. 027314	0. 299468
Regression Error	0. 050314	0. 000136	0. 133591	0. 218182	0. 000171	0. 000135	0. 057471	0. 139065	0. 224270	0. 000341	7. 593955	0. 017186	0. 008163	0. 092023

TABLE 8 -- (Continued)

Choice Mode--Transit

	Regression 1	Regression 2	Regression 3
Dependent Variable	6 Mode Transit	6 Mode Transit	6 Mode Transit
Multiple R	0.627	0.610	0.686
F	4.42	3.26	10.68
Degrees of Freedom (N-K-1)	34.	33.	36.
Multiple R^2	0.394	0.372	0.471
Intercept A	6.652728	21.921461	1.745251
Std. Error of Estimate	5.423760	5.601434	0.290196

Independent Variables	Regression 1	(A & Y deleted by regression)				Regression 2	(B¹ & Y deleted by regression)					Regression 3		
	B^1	N	S	B^2	R^s	N	D	A	B^2	S	R^s	D	S	F
Partial R	0.380	-0.355	0.174	0.129	-0.048	-0.339	0.271	-0.218	0.193	0.077	0.052	0.576	-0.471	0.295
F	5.74	4.92	1.06	0.57	0.08	4.27	2.61	1.65	1.28	0.20	0.09	17.85	10.26	3.44
Simple Correlations	0.477	-0.468	-0.320	0.274	-0.049	-0.468	0.320	-0.091	0.274	-0.320	-0.049	0.520	-0.313	0.323
R^2 with Rest of Model	0.294	0.732	0.751	0.155	0.387	0.752	0.242	0.319	0.135	0.764	0.528	0.057	0.019	0.040
Standardized B*	0.3808	-0.5724	0.2762	0.1099	-0.0481	-0.5723	0.2560	-0.2149	0.1677	0.1257	0.0598	0.5275	-0.3920	0.2295
Regression Error	0.1589	0.2581	0.2678	0.1453	0.1705	0.2769	0.1584	0.1672	0.1483	0.2836	0.2008	0.1248	0.1224	0.1237
Metric B	0.000310	-0.224287	0.170406	0.000078	-0.010748	-0.224261	0.000430	-7.619840	0.000119	0.077555	0.013354	0.572651	-2.262057	0.742574
Regression Error	0.000130	0.101148	0.165197	0.000103	0.038095	0.108512	0.000266	5.925505	0.000105	0.174996	0.044844	0.135536	0.706142	0.400374

TABLE 9 -- Elapsed Time

	Regression 1						Regression 2							Regression 3	
Dependent Variable						7 Elapsed Time							7 Elapsed Time		7 Elapsed Time
Multiple R						0.766							0.775		0.601
F						7.82							6.88		10.44
Degrees of Freedom (N-K-1)						33.							32.		37.
Multiple R^2						0.587							0.601		0.361
Intercept A						0.255866							0.168535		-0.619929
Std. Error of Estimate						0.069972							0.069852		0.023463
Independent Variables	S	M^b	P	R^s	N	Y	S	M^b	R^s	P	D	N	Y	S	B^2
Partial R	0.573	0.561	-0.333	-0.289	-0.140	-0.061	0.592	0.582	-0.261	-0.220	-0.183	-0.173	-0.083	0.534	0.290
F	16.12	15.19	4.11	3.02	0.66	0.13	17.29	16.36	2.35	1.62	1.11	0.98	0.22	14.76	3.41
Simple Correlations	0.526	0.300	-0.203	0.165	0.241	0.013	0.526	0.300	0.165	-0.203	-0.003	0.241	0.013	0.549	0.325
R^2 with Rest of Model	0.733	0.271	0.766	0.808	0.757	0.195	0.751	0.321	0.814	0.820	0.444	0.765	0.205	0.024	0.024
Standardized B*	0.8690	0.5108	-0.4687	-0.4436	-0.1844	-0.0441	0.9309	0.5483	-0.3965	-0.3352	-0.1580	-0.2282	-0.0591	0.5113	0.2456
Regression Error	0.2164	0.1310	0.2312	0.2554	0.2269	0.1247	0.2237	0.1356	0.2588	0.2632	0.1497	0.2303	0.1253	0.1331	0.1331
Metric B	0.008256	0.007865	-0.001300	-0.001526	-0.001113	-0.000002	0.008838	0.008443	-0.001364	-0.000930	-0.000004	-0.001377	-0.000002	0.219966	0.083030
Regression Error	0.002056	0.002018	0.000641	0.000878	0.001369	0.000004	0.002125	0.002087	0.000890	0.000730	0.000004	0.001390	0.000004	0.057249	0.044979

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